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THE EARTHQUAKE SEQUENCE NEAR DANVILLE, CALIFORNIA, 1970*

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ABSTRACT

Several thousand small earthquakes, with magnitudes ranging up to 4, occurred near Danville, California, during May, June, and July 1970. Seven temporary seismographs were installed near the epicentral region to augment an existing telemetered network within 1 day after the first felt earthquake. The dense concentration of 10 seismographs within 12 km of the seismic activity and the existence of a reversed seismic-refraction profile through the region permitted a very detailed study of this earthquake sequence. Over 400 events with magnitude greater than 0.5 were located with an average accuracy of ±1 km. The main earthquake region was approximately spherical: 1 km in radius, 6 km deep, and centered about 5 km southeast of Danville, 40 km east of San Francisco. Fault-plane solutions indicate that faulting associated with the earthquakes was of the right-lateral strike-slip type, with a strike of N 35°W.

The earthquakes cannot readily be related to any previously identified geological structure or fault. They suggest that active right-lateral faulting is not restricted to the mapped fault trace of the Calaveras fault. This result implies that not all of the sources of future earthquakes in the San Francisco Bay region can be identified by surface mapping alone. The use of small earthquakes to map active faulting at depth may help to identify areas of potential earthquake hazards.

Introduction

An unusual sequence of earthquakes occurred near Danville, California, in 1970. The sequence began in early May, culminated in peaks of activity during the last week of May and the second week of June, and died out slowly during the following several months. The shocks during the most active period from May 25 to June 15 stand out as a swarm in that no single earthquake predominated among the large number of events. They occurred unexpectedly 2 km east of the surface trace of the Calaveras fault, in an area where no faults or unusual seismic activity had been noted. Their occurrence shows that not all seismic hazards in the Danville area are evident at the surface.

Minor earthquakes preceded the Danville swarm, and activity continued in the region at a much diminished level for many months. For this paper, we studied earthquakes near Danville for a 3-month period from May 1 to July 31, 1970. Inasmuch as four permanent stations were within 20 km and surrounded the epicentral region, we obtained a complete record of all earthquakes above magnitude 1.2. These four stations were supplemented by over 30 other permanent stations in the San Francisco Bay region as well as 7 (later 8) temporary stations installed in the earthquake area shortly after the first felt earthquake on May 26. The dense concentration of seismographs permitted determination of the hypocenter and focal mechanism of small earthquakes with exceptional precision.

Geological Setting

The Danville area is located 40 km east of San Francisco in the Diablo Range, part of the coast ranges of central California. Figure 1 is an index map of the San Francisco

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Bay region with the center of the earthquake swarm marked by ×. A generalized geological map of the region is shown in Figure 2. The Danville area is east of the major active strike-slip faults: the San Andreas, Hayward, and Calaveras faults; and is west of the Mount Diablo fault which is of uncertain age and displacement. Folds and faults in the region trend northwest and involve rocks as old as Jurassic and as young as Holocene. Most of these rocks are sandstone and shale; some are

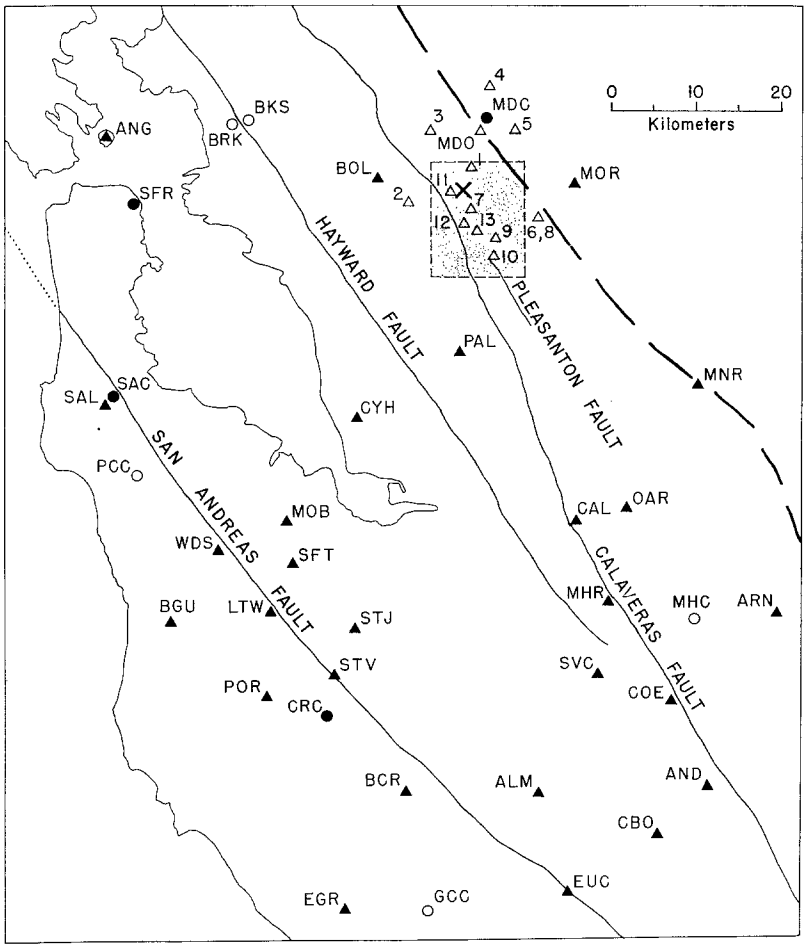

FIG. 1. Index map of San Francisco Bay region showing major faults and seismograph stations. The *shaded square* is the Danville area with the center of the earthquake swarm marked by ×. △ denotes USGS temporary stations, and ▲ USGS permanent stations. Stations operated by the University of California, Berkeley, are indicated by ○, and that by the Earthquake Mechanism Laboratory, ●. *Dashed curve* is the seismic-refraction profile established by Stewart (1968).

volcanic, ultramafic, and metamorphic rocks (see explanation of Figure 2). Some of the serpentine and related Franciscan rocks, such as those at Mount Diablo, could form piercement structures (see discussion by Pampeyan, 1963, p. 17–20). Basalt, andesite, rhyolite, and other extrusive and intrusive rocks of Cenozoic age occur in the area, but there is no evidence of Holocene volcanism.

The area southwest of Danville in the immediate vicinity of the earthquakes described in this paper is underlain by the Orinda Formation of Pliocene age. This formation may be as much as 3 km thick (Hall, 1958, p. 29), and it consists of sandstone, claystone, conglomerate, limestone, and tuff, most of which apparently was

deposited in fresh or brackish water. The formation is so poorly exposed that the structure is uncertain near the earthquake area (see map by Geological Society of Sacramento, 1964). Vegetation patterns on aerial photographs suggest that some of

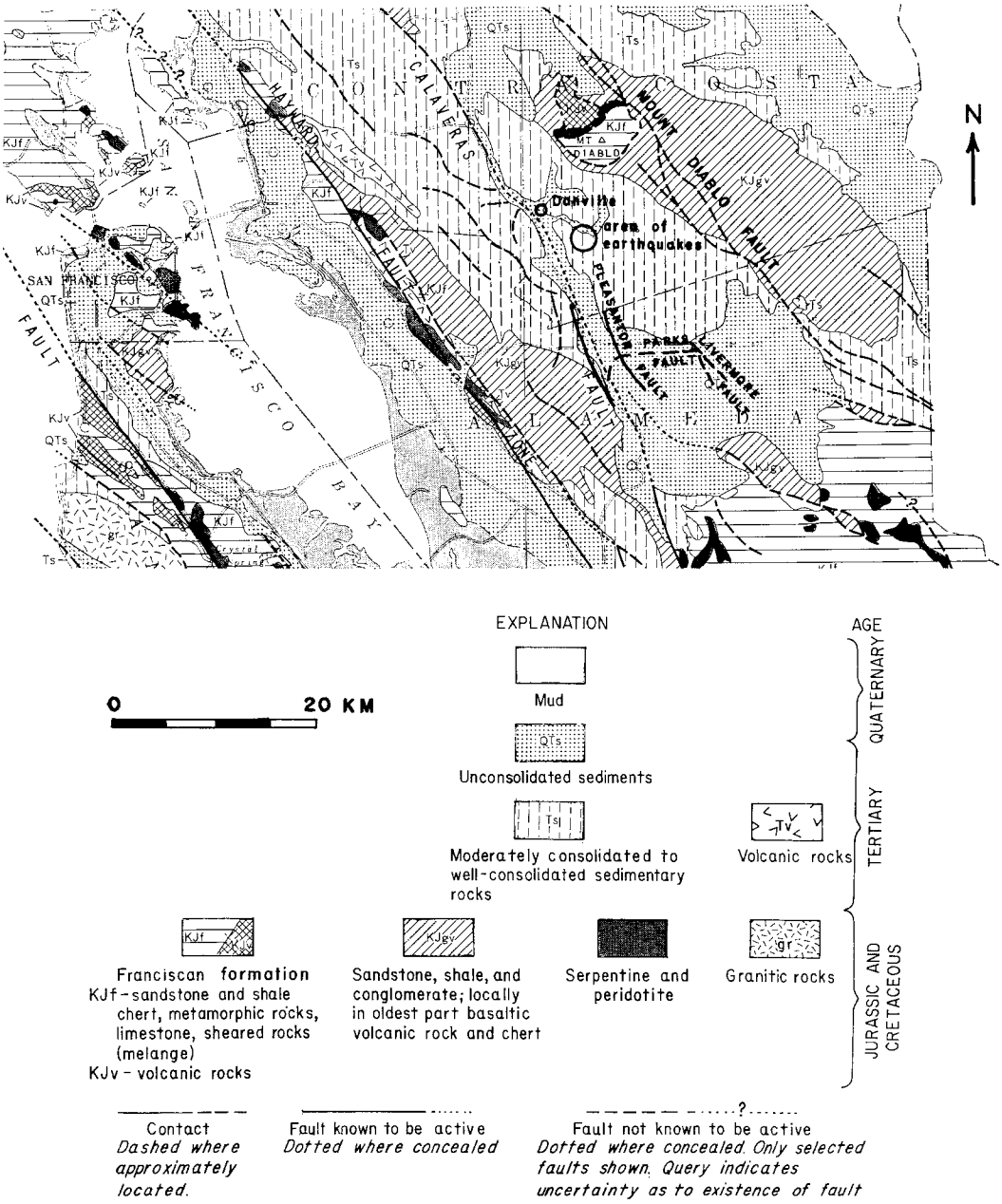

FIG. 2. Generalized geological map of San Francisco Bay region from Schlocker (1968). Parks and Livermore faults added from map by Rogers (1966); Pleasanton fault and recent surface break along Calaveras fault added from map by Brown (1970).

the beds are vertical and that the structure is complicated. No faults have been mapped in the vicinity of the earthquakes, but both the Pleasanton and Livermore faults (Figure 2) trend toward the epicentral area. Fences bordering Camp Parks show right-lateral movement of 8 to 10 cm where they cross the Pleasanton fault

(Gibson and Wollenberg, 1968; Radbruch, 1968). Evidence for surface rupture on the Calaveras fault near Danville is summarized by Radbruch (1968, p. 50–53).

A long crustal seismic-refraction profile through the Diablo Range was established in 1967 by Stewart (1968, and private communication, 1970). The profile, from Benicia to Panoche, was about 200 km long and had 5 shotpoints distributed along it. It passed through the vicinity of the earthquake area about 5 km to the northeast (see Figure 1), and provides useful information on the crustal structure which is needed to locate earthquakes. The Diablo Range is characterized seismically by a northwest-dipping layered structure. P-velocities of the upper crust determined from reversed refraction data are 3.3, 5.0, and 5.7 km/sec at successively greater depths. The bottom of the Franciscan formation is placed at a depth of 11 to 15 km, and the base of the crust at about 28 km. P-velocities for the lower crust and upper mantle determined from unreversed refraction data are 6.9 and 8.2 km/sec, respectively.

Seismograph Stations

The Danville earthquake sequence occurred in a region well covered by seismograph stations (Figure 1). For many decades, the University of California, Berkeley, has operated a regional seismographic network in northern California. In the past few years, the Earthquake Mechanism Laboratory (EML) of the National Oceanic and Atmospheric Administration has operated several stations along the San Andreas fault as well as one at Mt. Diablo (MDC). Since 1967, the National Center for Earthquake Research (NCER) of the U. S. Geological Survey has gradually built up a dense microearthquake network in central coastal California with about 60 stations operating during the Danville earthquake sequence.

At the beginning of the Danville swarm, about 40 permanent stations were operating within 100 km of Danville. Four critical stations surrounding the earthquake swarm were within 20 km: EML's MDC station and NCER's BOL, MOR, and PAL stations. The first felt earthquake (magnitude = 3.7) occurred at 3:10 p.m. local time, May 26, 1970. In order to obtain the data needed for precise determination of the hypocenter and focal mechanism of the Danville earthquakes, seven temporary seismographs were dispatched early the next morning. Four of them began recording by the afternoon of May 27, and all of the stations were operating within 2 days of the first felt earthquake.

Station data given in Table 1 include information on the coordinates, elevation, and recording periods. In addition, the epicentral distance and azimuth from the center of earthquakes to each station are also listed. This center is taken to be the average of all of the earthquake epicenters studied in this paper. Only data from stations within 100 km of the earthquake center were used in the determination of the hypocenter. For each station, the number of times that it has contributed P arrivals is also given. Several stations were omitted because of their lower sensitivity instruments or because they were situated in noncritical locations for the Danville earthquakes.

All but one of the temporary stations utilized the portable seismograph units described in detail by Eaton, O'Neill, and Murdock (1970). There were 13 sites for these portable seismographs, but only 6 (and later 7) sites were occupied at one time. The permanent stations operated by the U.S. Geological Survey consist of vertical-component, short-period seismometers with signals telemetered via phone lines to Menlo Park. The signals are recorded on 16-mm film and on magnetic tape. One temporary station employed equipment for a permanent station, but its signal was transmitted directly to Menlo Park via radio for recording.

TABLE 1. STATION DATA**

STN	DIST	AZ	NO	LAT(N)	LONG(W)	ELV	SC	NOTE
MD07	1.9	168	103	37-46.98	121-56.35	183	-0.07	6/12-7/28
MD11	2.1	275	47	37-48.10	121-58.05	156	0.04	6/25-7/29
MD01	3.1	8	207	37-49.66	121-56.34	204	-0.06	5/28-6/5;6/12-7/29
MD12	3.5	189	44	37-46.13	121-57.01	152	-0.03	6/27-7/27
MD13	4.6	165	35	37-45.62	121-55.83	219	0.03	7/2-7/29
MD09	6.2	149	50	37-45.13	121-54.49	145	0.09	6/25-7/29
MD02	7.1	262	165	37-47.47	122-01.43	341	-0.06	5/27-6/5;6/12-6/25
MD0	7.6	10	203	37-52.04	121-55.69	719	0.04	5/27-6/10;6/12-7/29
MD10	7.9	159	46	37-44.00	121-54.72	123	0.19	6/24-7/27
MD03	8.7	329	139	37-52.03	121-59.64	195	0.14	5/28-6/5;6/12-6/24
MD08	8.7	110	77	37-46.39	121-51.07	201	0.05	6/12-6/27
MD06	8.8	109	80	37-46.42	121-51.00	198	0.00	5/27-6/5
MDC@	9.1	14	244	37-52.77	121-55.10	1120	0.09	
MD05	9.2	36	149	37-52.02	121-52.91	268	-0.04	5/27-6/5;6/12-6/24
BOL	10.6	280	421	37-48.97	122-03.72	610	0.05	
MOR	12.5	84	404	37-48.68	121-48.15	792	-0.07	
MD04	12.9	11	79	37-54.87	121-54.95	280	-0.21	5/28-6/5
PAL	18.8	183	424	37-37.88	121-57.37	463	-0.02	
BKS#	27.0	288	37	37-52.60	122-14.10	276	-0.05	
BRK#	29.0	286	6	37-52.40	122-15.60	81	-0.11	
CYH	29.8	206	403	37-33.54	122-05.62	38	-0.30	
MNR	35.4	130	148	37-35.68	121-38.22	500	0.01	
CAL	40.8	162	88	37-27.07	121-47.95	265	-0.03	
OAR	41.7	153	9	37-27.89	121-43.87	990	0.13	6/10-6/12
ANG	43.3	279	327	37-51.68	122-25.77	223	-0.12	
SFT	48.4	205	66	37-24.31	122-10.55	143	0.12	
SAL	49.1	240	353	37-34.56	122-25.40	335	0.05	
PCC#	51.0	229	8	37-30.00	122-22.90	91	-0.10	
WDS	51.4	214	67	37-25.08	122-16.33	280	0.20	
MHR	51.6	161	37	37-21.57	121-45.38	518	0.28	
STJ	53.3	194	22	37-20.04	122-05.50	114	0.40	
LTW	54.6	205	40	37-21.22	122-12.25	270	0.13	
MHC#	57.4	152	37	37-20.50	121-38.50	1282	0.36	
SVC	59.1	165	36	37-17.11	121-46.35	128	0.88	
STV	59.4	196	29	37-17.07	122-07.42	357	0.23	
BGU	61.5	215	4	37-20.60	122-20.32	158	0.68	
ARN	61.8	144	36	37-20.96	121-31.96	628	0.38	
POR	64.1	202	49	37-15.81	122-12.78	182	0.60	
COE	64.8	158	10	37-15.46	121-40.35	366	0.60	
BCR	71.3	186	14	37-09.67	122-01.57	634	0.51	
ALM	71.7	173	24	37-09.50	121-50.82	244	0.42	
AND	76.2	158	14	37-09.74	121-37.45	244	0.74	
CBO	79.6	164	8	37-06.71	121-41.33	192	0.50	
EUC	84.0	172	8	37-03.05	121-48.55	427	0.69	
GCC#	85.6	183	3	37-01.80	121-59.80	122	1.61	
EGR	86.1	190	9	37-02.08	122-06.27	442	0.35	
CAN	95.2	155	6	37-01.51	121-29.00	329	1.22	
PMR	96.5	167	3	36-57.19	121-41.70	94	1.64	

** STN --- STATION NAME.
DIST -- DISTANCE IN KM FROM THE CENTER OF EARTHQUAKES TO STATION.
AZ ---- AZIMUTHAL ANGLE IN DEGREES FROM THE CENTER TO THE STATION.
NO ---- NUMBER OF EARTHQUAKES IN WHICH THE STATION WAS USED.
LAT --- LATITUDE (NORTH) OF THE STATION IN DEGREES AND MINUTES.
LONG -- LONGITUDE (WEST) OF THE STATION IN DEGREES AND MINUTES.
ELV --- ELEVATION OF THE STATION IN METERS.
SC ---- STATION CORRECTION IN SEC.
NOTE -- RECORDING PERIODS OF THE STATION. IF THIS COLUMN IS BLANK, THEN THE STATION HAS BEEN OPERATED CONTINUOUSLY.
@ STATION OPERATED BY THE EARTHQUAKE MECHANISM LABORATORY.
# STATION OPERATED BY THE UNIVERSITY OF CALIFORNIA.

Data Processing

From May to July, 1970, several thousand earthquakes near Danville were recorded. Most of them were exceedingly small (magnitude less than 0), and locating all these events was not practical. A manageable number of earthquakes for processing with current techniques is about 500. Consequently, we aimed for that number, and tried to produce a uniform data set including all earthquakes above magnitude 1.

In the routine processing of data recorded by our microearthquake network, all seismic events within the network that have a *F-P* duration of 10 sec or greater are timed and analyzed. The *F-P* duration is defined rather arbitrarily as the duration time in seconds from the onset of the first *P*-arrival to the point where the trace amplitude (peak-to-peak) falls below 1 cm as it appears on a Geotech film viewer (Model 6585). Earthquakes near Danville that had been processed in the routine manner were identified, and their *P* arrivals were then augmented by readings from EML's MDC station, our temporary stations, and preliminary readings of seismographic stations issued by the University of California at Berkeley. Usually only sharp onsets of *P* arrivals were read. Reading precision was about ± 0.05 sec. Since about 100 seismograph stations were operating in central California, we concentrated on the close-in stations. About half of the 426 earthquakes studied had several readings from the temporary stations. The number of *P* arrivals used for calculating individual hypocenters averaged 11 and was never less than 6.

The earthquake parameters, origin time (t), focal coordinates (x, y, z), and magnitude, were computed using a program written by Lee (1970). Hypocenters were determined by Geiger's method (Geiger, 1912). The usual regression of *P*-residuals was replaced by a step-wise multiple regression for faster and generally better hypocenter solution. *P* travel times from a trial hypocenter to the stations and their partial derivatives were computed assuming a horizontal multi-layer model by a technique introduced by Eaton (1969).

For the purpose of locating earthquakes in the Danville area, S. W. Stewart (private communication, 1970) suggested the following simplified model:

Depth (km)	P velocity (km/sec)
0 to 3.7	3.46
3.7 to 11.3	5.51
11.3 to 28.0	6.86
below 28.0	8.00

To minimize undesirable effects of hypocenter adjustment across sharp discontinuities of *P* velocity with depth, Stewart's model was smoothed by a 10-layer approximation (Figure 3). This 10-layer model was used to locate 30 well-recorded events. The station residuals were then used as station corrections in the next location, and the procedure was repeated. By then, the station residuals were down to about ± 0.02 sec. The station corrections (see Table 1) obtained from these 30 earthquakes were used in the location of all of the Danville earthquakes. To minimize the effect of unevenly distributed stations and the expected deviations from the model at greater distances, stations beyond 25 km were given reduced weights, which decreased linearly from 1 at 25 km to 0 at 100 km and beyond.

Magnitudes of the Danville earthquakes were computed as the average of $\overline{XMAG}$ and $\overline{FMAG}$. $\overline{XMAG}$ is the average of $XMAG$ at various stations, based on the maximum trace amplitude, and is computed according to Eaton, O'Neill, and Murdock (1970, p. 1160–1162). $\overline{FMAG}$ is the average of $FMAG$ at various stations based on

F-P duration, and is computed by a method similar to the one described by Tsumura (1967). Because of the difficulties in obtaining maximum trace amplitude from seismograms recording on 16-mm film and in calibrating the instruments, it is easier to obtain *FMAG* at a given station than it is *XMAG*. A sample of earthquakes with well-determined *XMAG* was used to establish the following empirical scale:

$$FMAG = -1.2 + 2.2 \log \tau + 0.0033\Delta$$

where τ is the *F-P* duration in seconds and Δ, the epicentral distance in km.

In the case of earthquakes recorded at distances beyond several hundred kilometers, the coefficient of Δ in the above equation would be a negative constant. This is due

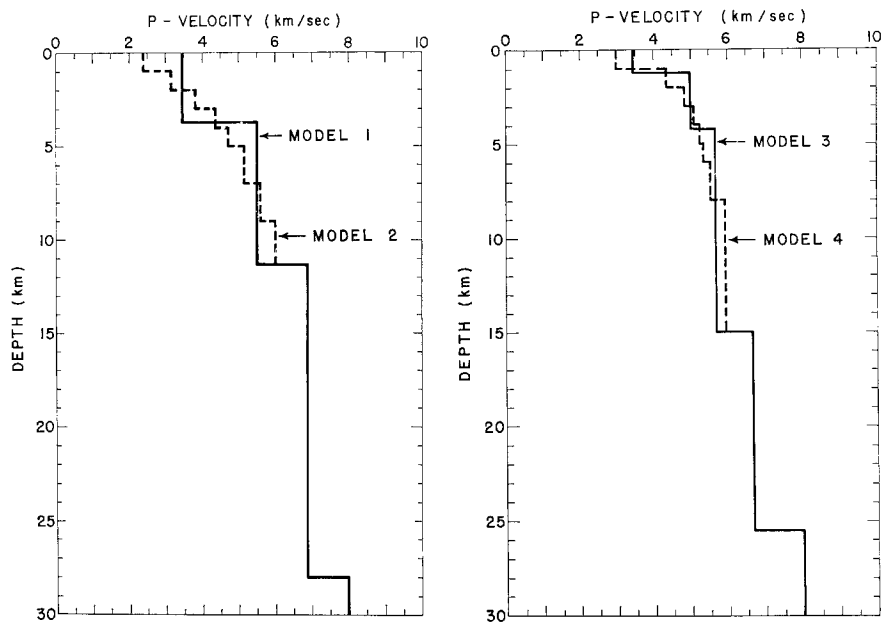

FIG. 3. *P* velocity versus depth for determination of hypocenters. Model 1 was suggested by S. W. Stewart (private communication, 1970) for the Danville area. Model 2 is a smoothed approximation of model 1 and was used in determination of hypocenters. Model 3 is from Stewart (1968) for the Diablo Range, and model 4 is a smoothed approximation of model 3.

to the fact that as the distance increases, the interval between the arrival of *P* and that of the surface waves also increases. However, this is not the case for local earthquakes recorded by high-gain, vertical-component seismometers at distances less than 100 km. Seismic phases are poorly separated, and the coda length (and hence τ) probably depends mainly on the back-scattering of seismic waves (Aki, 1969). Generally, such waves diminish slowly in amplitude as distance increases.

An independent check against the final magnitude assigned to the Danville earthquakes was made. Comparison with magnitudes of 34 Danville earthquakes published by the University of California at Berkeley (Zanetti and Miller, 1971) indicated a general agreement within $\frac{1}{4}$ unit and without systematic departures.

HYPOCENTERS AND THEIR ACCURACY

An earthquake is generally described by five parameters: origin time, latitude, longitude, focal depth of the hypocenter, and magnitude. Other parameters describing an

earthquake relate to the length and direction of faulting, the seismic moment, and the stress drop, etc. The former parameters and other values useful in ascertaining the quality of hypocenters are listed in Table 2. Because of the limited space on a punched card, the standard error of the origin time is not given. However, it is related to the root-mean-square error and is commonly less than 0.1 sec. Uncertainty in magnitude was estimated to be $\pm\frac{1}{4}$ unit; it was derived mainly from comparison with magnitudes published by the University of California for the larger events. In this section, we will deal with the accuracy of the hypocenters because of its significance in defining the size and shape of the earthquake area and its relation to geological faults.

Uncertainty in the hypocenter location has two sources: random error and systematic error. Random error in the hypocenter arises mainly from errors in reading P arrivals, whereas systematic error arises mainly from the uncertainty of the P-velocity model. The root-mean-square error (RMS) indicates the level of minimization of P residuals with respect to the assumed model. The average for 426 Danville earthquakes is 0.06 sec, which is close to the reading error of ± 0.05 sec. This is a good indication that all errors associated with reading P arrivals are accounted for in the RMS error. Similarly, the average standard error for the epicenter is 0.28 km and that for the focal depth is 0.38 km. These low figures suggest that the hypocenters for the Danville earthquakes have been determined with a high precision (i.e. random errors were small).

Systematic error in the hypocenter, however, cannot be ascertained without controlled experiments, e.g., known explosions in the focal region. Nevertheless, some indications of the systematic error can be found by numerical experiments. For this purpose, 25 selected Danville earthquakes were located using four different P-velocity models (see Figure 3). The results indicated that the differences in the epicenter were usually less than 0.5 km; but the differences in focal depth were much larger, 1 km or more, depending also on the availability of close-in stations. We have ignored the effect of lateral variations of P velocity, which can also introduce bias in determining hypocenters. However, there is no evidence to suggest that there are large lateral variations in crustal structure near Danville. Furthermore, we used, mostly, stations within 25 km to locate hypocenters.

In the above discussion, we have assumed that the coordinates of the seismographic stations are accurate and that the stations are evenly distributed by azimuth and distance (Bolt, 1960). To study the effect of station distribution, we relocated 20 artificial earthquakes with various combinations of stations. We found that the maximum azimuthal gap between stations (α) and the minimum station distance from the epicenter (β) are useful parameters. To obtain a reliable epicenter, α should be less than 180°; to obtain reliable focal depth, β should be less than the focal depth. For the Danville earthquakes, the first condition was met in all but one case; the second condition was met about one-half of the time when the temporary stations were recording.

Because available stations (especially close-in ones) changed from time to time for the Danville earthquakes, we also carried out the following numerical experiment. Twelve earthquakes were selected on the basis of best station distribution. We then located these earthquakes using only the permanent stations and compared the hypocenter solutions with those obtained by using all stations. The differences between the hypocenters were found to be small, usually within one standard error of the epicenter and two standard errors of the focal depth. Recently, the program written by Lee (1970) was revised to include azimuthal weighting similar to that introduced by

TABLE 2 LIST OF DANVILLE EARTHQUAKES*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
MAY 1	4	36	16.6	37- 48.0	121- 56.6	5.0	1.2	7	99	9.0	0.03	0.2	0.3	B
1	4	36	59.4	37- 47.9	121- 56.8	5.4	1.0	7	99	9.4	0.02	0.1	0.2	B
1	4	58	55.4	37- 47.9	121- 56.8	5.0	1.3	9	95	9.3	0.06	0.3	0.5	B
1	6	33	44.4	37- 47.9	121- 56.6	6.0	1.1	7	100	9.2	0.03	0.2	0.3	B
1	8	56	11.6	37- 48.1	121- 56.4	5.0	1.3	10	94	8.8	0.09	0.4	0.6	B
12	13	17	50.3	37- 48.0	121- 56.6	5.7	0.9	7	99	9.1	0.00	0.0	0.1	B
15	7	16	18.4	37- 48.3	121- 56.4	6.2	1.6	7	98	8.6	0.03	0.2	0.3	B
15	13	12	55.9	37- 48.1	121- 56.4	5.4	1.6	7	99	8.9	0.02	0.2	0.3	B
16	2	14	29.6	37- 48.2	121- 56.5	5.0	1.9	8	95	8.6	0.12	0.6	0.9	B
16	3	11	44.7	37- 48.1	121- 56.2	6.0	1.4	7	100	8.7	0.02	0.1	0.2	B
16	7	21	4.4	37- 48.2	121- 56.6	5.0	1.5	9	96	8.7	0.05	0.2	0.4	B
16	13	1	49.9	37- 48.2	121- 56.4	5.9	1.1	7	98	8.6	0.06	0.4	0.6	B
22	0	29	14.8	37- 48.4	121- 57.0	5.0	2.0	19	101	8.6	0.14	0.5	0.7	B
22	0	46	35.8	37- 48.0	121- 56.4	5.9	1.9	7	100	9.0	0.02	0.1	0.2	B
22	10	39	57.3	37- 48.4	121- 56.5	5.0	2.6	25	88	8.3	0.10	0.3	0.4	B
22	19	41	13.2	37- 47.9	121- 56.7	5.7	1.9	6	163	10.5	0.02	0.2	0.2	B
22	20	18	20.7	37- 48.2	121- 56.6	5.0	1.4	7	97	8.8	0.01	0.1	0.2	B
25	0	42	40.8	37- 48.1	121- 57.0	3.8	2.7	21	89	9.0	0.17	0.6	1.4	B
25	0	48	20.2	37- 48.0	121- 56.8	5.5	1.2	6	98	9.2	0.02	0.1	0.3	B
25	1	8	8.3	37- 48.1	121- 56.7	5.6	1.3	8	96	9.0	0.02	0.1	0.1	B
25	2	0	59.4	37- 48.0	121- 56.6	5.0	1.0	6	99	9.0	0.01	0.1	0.2	B
25	2	6	40.6	37- 48.1	121- 56.8	5.5	1.0	7	98	9.0	0.02	0.2	0.3	B
25	4	38	38.6	37- 48.4	121- 56.6	5.0	0.9	7	98	8.3	0.06	0.4	0.7	B
25	4	40	55.3	37- 48.2	121- 56.8	5.8	0.8	6	98	8.8	0.03	0.3	0.4	B
25	4	45	2.6	37- 48.1	121- 56.5	5.9	1.1	7	99	9.0	0.04	0.2	0.3	B
25	4	56	58.6	37- 48.6	121- 56.5	7.0	1.1	7	98	8.0	0.09	0.9	1.1	B
25	5	0	23.6	37- 47.9	121- 56.9	5.8	1.3	8	95	9.4	0.01	0.1	0.1	B
25	5	26	59.8	37- 47.9	121- 56.7	5.8	1.0	7	100	9.3	0.01	0.1	0.1	B
25	5	30	12.8	37- 48.2	121- 57.2	6.2	0.8	6	102	8.9	0.08	0.6	0.9	B
25	7	38	2.3	37- 47.9	121- 56.6	5.8	1.2	7	100	9.3	0.01	0.1	0.1	B
25	7	41	45.2	37- 48.0	121- 56.9	5.0	1.7	11	97	9.2	0.10	0.5	0.7	B
25	8	13	32.1	37- 48.4	121- 56.9	5.0	2.7	12	90	8.6	0.08	0.4	0.5	B
25	8	16	58.4	37- 48.0	121- 56.6	5.0	0.8	6	99	9.2	0.04	0.3	0.5	B
25	8	26	53.1	37- 48.5	121- 56.7	6.9	1.2	6	102	8.3	0.07	0.6	0.8	B
25	8	27	56.1	37- 47.8	121- 56.9	5.7	1.5	7	99	9.5	0.02	0.1	0.2	B
25	9	43	24.4	37- 47.9	121- 56.9	5.5	1.7	14	96	9.4	0.05	0.2	0.3	B
25	12	30	43.4	37- 48.2	121- 56.8	5.0	1.4	7	98	8.7	0.07	0.4	0.8	B
25	13	5	11.6	37- 48.2	121- 56.6	6.0	1.1	7	98	8.8	0.04	0.3	0.3	B
25	13	31	32.2	37- 48.4	121- 56.5	5.0	1.7	7	96	8.4	0.09	0.4	0.7	B
25	18	42	28.6	37- 48.5	121- 56.7	4.2	2.9	21	90	8.2	0.10	0.4	0.5	B
25	18	42	59.6	37- 48.0	121- 56.8	3.8	3.0	13	88	9.1	0.12	0.5	1.3	B
25	18	46	17.9	37- 47.9	121- 56.6	5.0	1.7	14	92	9.3	0.07	0.3	0.4	B
25	19	23	47.4	37- 48.3	121- 56.6	5.2	1.0	6	99	8.5	0.00	0.0	0.1	B
25	19	26	22.3	37- 48.3	121- 56.7	5.8	1.9	7	97	8.5	0.04	0.3	0.4	B
25	19	26	48.4	37- 48.2	121- 56.9	5.0	1.7	7	99	8.9	0.03	0.2	0.4	B
25	20	8	25.8	37- 48.1	121- 56.8	5.9	1.7	7	98	9.1	0.02	0.1	0.2	B
25	20	26	34.9	37- 48.0	121- 56.9	5.0	2.4	9	98	9.2	0.09	0.5	0.7	B
25	21	26	6.9	37- 48.3	121- 57.0	6.8	1.1	6	102	8.7	0.07	0.6	0.9	B
25	21	31	35.6	37- 48.2	121- 56.6	5.7	1.4	7	97	8.7	0.04	0.2	0.3	B
25	21	33	2.1	37- 48.1	121- 56.8	5.9	1.6	7	98	9.0	0.03	0.2	0.2	B
26	1	29	54.6	37- 50.5	121- 57.9	5.3	1.8	16	132	5.8	0.14	0.6	0.6	B
26	2	8	34.8	37- 48.3	121- 56.9	5.0	1.4	6	169	10.1	0.05	0.4	0.6	B
26	2	9	0.6	37- 48.4	121- 56.2	7.3	1.6	7	97	8.2	0.10	0.6	0.9	B
26	4	37	14.4	37- 50.9	121- 57.6	5.8	1.7	14	136	5.0	0.15	0.9	0.8	B
26	5	31	34.7	37- 48.5	121- 56.7	5.0	1.3	7	99	8.2	0.05	0.3	0.6	B
26	9	30	46.1	37- 48.1	121- 56.9	5.7	1.5	7	98	9.0	0.02	0.2	0.2	B
26	10	16	19.9	37- 48.4	121- 57.3	5.0	1.3	7	104	8.8	0.06	0.4	0.7	B
26	10	30	49.8	37- 48.5	121- 57.1	5.0	1.8	9	102	8.5	0.05	0.3	0.4	B
26	10	42	41.5	37- 48.5	121- 56.9	5.0	1.5	11	100	8.3	0.08	0.4	0.5	B
26	11	15	16.2	37- 48.4	121- 57.0	5.0	1.8	13	101	8.5	0.06	0.3	0.4	B

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
MAY 26	16	47	8.6	37- 48.5	121- 57.0	5.0	2.5	10	170	9.9	0.06	0.4	0.4	B
26	18	56	45.4	37- 47.4	121- 56.9	5.0	1.6	8	102	10.3	0.10	0.6	1.0	B
26	22	10	16.5	37- 48.2	121- 56.8	4.0	1.9	15	89	8.9	0.12	0.5	1.2	B
26	22	10	23.1	37- 48.1	121- 56.8	3.8	2.7	14	88	9.1	0.12	0.5	1.2	B
26	22	10	33.8	37- 48.5	121- 56.8	6.3	3.7	6	103	8.3	0.05	0.5	0.5	B
26	22	19	54.6	37- 48.3	121- 57.0	5.0	2.5	18	91	8.7	0.11	0.4	0.6	B
26	22	42	21.4	37- 48.5	121- 56.8	5.0	1.9	6	100	8.2	0.03	0.2	0.4	B
26	22	43	2.8	37- 48.3	121- 56.3	7.7	1.8	7	98	8.4	0.12	0.4	0.5	B
26	23	6	43.3	37- 48.4	121- 56.6	5.0	2.8	27	88	8.4	0.09	0.3	0.4	B
26	23	33	38.8	37- 48.0	121- 56.9	5.0	1.6	15	88	9.1	0.06	0.2	0.3	B
26	23	33	40.0	37- 47.9	121- 57.2	3.8	3.6	17	98	9.4	0.12	0.4	1.0	B
26	23	37	44.3	37- 48.1	121- 57.1	5.0	1.7	9	100	9.1	0.04	0.2	0.3	B
26	23	38	31.8	37- 48.3	121- 56.6	5.4	1.4	7	97	8.5	0.01	0.1	0.1	B
26	23	40	33.1	37- 47.9	121- 56.4	6.2	2.1	9	92	9.2	0.05	0.3	0.4	B
26	23	43	11.5	37- 47.9	121- 56.6	5.7	1.1	7	100	9.2	0.03	0.2	0.3	B
26	23	44	29.0	37- 47.4	121- 56.8	5.0	1.3	7	103	10.2	0.10	0.7	1.2	B
26	23	58	27.5	37- 48.0	121- 56.5	5.0	2.2	9	100	9.1	0.07	0.3	0.5	B
27	0	3	17.7	37- 48.1	121- 56.1	5.6	1.2	7	100	8.7	0.03	0.2	0.3	B
27	0	19	59.3	37- 48.0	121- 56.3	5.0	1.7	8	101	9.0	0.05	0.3	0.5	B
27	0	21	22.2	37- 47.9	121- 56.6	5.8	1.2	7	100	9.3	0.02	0.2	0.2	B
27	0	42	46.4	37- 47.7	121- 57.1	4.9	2.4	18	94	9.8	0.12	0.4	1.1	B
27	0	46	36.7	37- 47.9	121- 57.4	5.0	0.9	6	99	9.5	0.03	0.3	0.5	B
27	0	54	1.3	37- 47.7	121- 56.4	5.0	1.0	7	103	9.6	0.07	0.4	0.7	B
27	1	17	35.3	37- 48.7	121- 56.0	6.5	1.3	7	96	7.7	0.09	0.5	0.6	B
27	1	19	0.8	37- 48.4	121- 56.1	5.0	0.8	6	98	8.3	0.05	0.4	0.9	B
27	1	22	45.0	37- 48.2	121- 56.5	5.9	1.4	7	98	8.7	0.04	0.3	0.4	B
27	1	45	1.3	37- 48.3	121- 56.6	5.0	1.4	8	96	8.6	0.11	0.6	0.9	B
27	2	4	58.9	37- 48.3	121- 56.2	5.5	1.4	7	98	8.4	0.03	0.2	0.3	B
27	2	35	3.3	37- 48.4	121- 56.4	5.0	1.8	9	96	8.2	0.07	0.3	0.5	B
27	3	12	45.8	37- 48.4	121- 56.2	6.0	1.2	7	97	8.2	0.07	0.5	0.7	B
27	5	0	41.5	37- 48.4	121- 56.6	5.0	1.5	7	97	8.4	0.05	0.3	0.6	B
27	5	36	39.7	37- 49.1	121- 57.6	10.0	1.3	7	111	7.7	0.24	0.4	0.4	B
27	6	3	15.5	37- 48.1	121- 56.2	7.5	1.6	7	100	8.7	0.12	0.4	0.5	B
27	6	22	8.8	37- 48.5	121- 56.6	5.0	1.1	7	97	8.2	0.03	0.2	0.4	B
27	7	47	52.6	37- 47.4	121- 56.5	5.8	0.8	7	105	10.2	0.02	0.1	0.1	B
27	8	1	11.4	37- 48.1	121- 56.5	5.8	1.8	9	95	8.8	0.02	0.1	0.1	B
27	8	3	50.6	37- 48.1	121- 56.5	6.3	0.9	6	99	9.0	0.01	0.2	0.3	B
27	10	49	23.8	37- 47.9	121- 57.0	5.9	1.3	7	98	9.4	0.02	0.1	0.2	B
27	11	11	40.1	37- 47.6	121- 56.6	5.0	0.7	7	103	9.8	0.03	0.2	0.4	B
27	13	58	13.0	37- 48.1	121- 56.9	5.4	1.3	7	98	9.0	0.04	0.3	0.4	B
27	16	48	23.4	37- 47.9	121- 56.6	5.8	1.8	8	93	9.2	0.04	0.2	0.3	B
27	17	0	54.0	37- 47.7	121- 56.5	5.9	0.9	7	102	9.5	0.02	0.1	0.2	B
27	19	46	28.9	37- 48.1	121- 56.7	5.0	1.0	6	98	9.0	0.07	0.5	1.2	B
28	0	50	18.5	37- 48.4	121- 56.1	5.7	1.3	9	90	6.7	0.06	0.3	0.6	B
28	1	4	6.8	37- 48.4	121- 55.9	5.6	1.1	10	85	6.7	0.04	0.2	0.3	B
28	1	11	56.8	37- 47.8	121- 56.6	5.7	1.2	11	88	7.2	0.04	0.2	0.3	B
28	2	47	4.7	37- 48.9	121- 56.8	5.1	2.7	24	89	6.1	0.12	0.3	0.5	B
28	6	23	32.6	37- 48.2	121- 56.7	5.8	2.1	21	50	7.1	0.07	0.2	0.3	B
28	9	39	43.4	37- 48.3	121- 56.5	4.8	1.0	11	71	7.0	0.08	0.3	0.4	B
29	2	28	32.7	37- 48.3	121- 56.4	5.5	2.0	16	50	2.5	0.06	0.2	0.3	A
29	2	38	5.8	37- 47.8	121- 56.8	5.7	1.9	16	53	3.5	0.04	0.1	0.1	A
29	2	53	7.5	37- 48.2	121- 57.0	4.4	3.1	33	46	2.8	0.10	0.2	0.3	A
29	2	54	17.5	37- 48.1	121- 56.6	5.6	2.3	12	74	2.8	0.03	0.1	0.2	A
29	2	55	35.4	37- 47.9	121- 56.9	5.2	1.1	11	75	3.4	0.05	0.2	0.3	A
29	2	55	48.7	37- 48.2	121- 56.9	5.1	3.7	36	46	2.8	0.13	0.3	0.4	A
29	2	57	35.7	37- 48.4	121- 56.6	5.5	2.5	11	75	2.3	0.04	0.2	0.2	A
29	2	58	39.1	37- 48.1	121- 56.7	6.2	1.3	12	73	3.0	0.03	0.1	0.2	A
29	3	1	10.7	37- 48.2	121- 56.4	6.2	1.3	13	72	2.7	0.04	0.2	0.2	A
29	3	8	48.6	37- 47.6	121- 56.4	6.2	1.1	12	79	3.8	0.04	0.2	0.3	A
29	3	9	4.0	37- 48.0	121- 56.9	5.0	1.7	6	98	7.6	0.02	0.1	0.3	B

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
MAY 29	3	11	32.9	37- 48.5	121- 56.4	5.4	2.4	20	50	2.2	0.06	0.2	0.2	A
29	3	13	15.1	37- 48.4	121- 56.4	5.0	3.0	30	50	2.3	0.08	0.2	0.3	A
29	3	14	44.2	37- 48.5	121- 56.0	5.6	1.6	13	68	2.2	0.06	0.2	0.3	A
29	3	16	37.7	37- 47.7	121- 56.6	6.0	1.4	13	77	3.6	0.03	0.1	0.2	A
29	3	16	49.9	37- 48.4	121- 56.1	5.4	2.1	13	54	2.3	0.06	0.2	0.3	A
29	3	26	55.3	37- 48.0	121- 56.9	6.1	2.3	16	53	3.2	0.06	0.2	0.2	A
29	3	34	37.8	37- 48.5	121- 56.3	5.2	1.5	13	69	2.2	0.03	0.1	0.2	A
29	3	37	37.3	37- 48.5	121- 56.3	5.3	1.3	13	68	2.2	0.03	0.1	0.1	A
29	3	42	14.7	37- 48.3	121- 56.4	5.9	1.4	13	71	2.5	0.02	0.1	0.1	A
29	4	9	45.6	37- 47.9	121- 57.2	6.2	1.7	15	53	3.5	0.04	0.2	0.2	A
29	4	15	18.9	37- 48.0	121- 56.8	6.4	1.3	13	73	3.1	0.06	0.3	0.3	A
29	4	45	56.7	37- 48.0	121- 56.7	6.1	1.5	13	74	3.1	0.05	0.2	0.2	A
29	4	51	43.4	37- 48.0	121- 56.8	6.2	1.2	13	74	3.2	0.05	0.2	0.2	A
29	5	22	34.8	37- 47.7	121- 57.3	6.3	1.2	12	76	3.9	0.04	0.2	0.2	A
29	5	53	46.6	37- 48.2	121- 56.6	5.7	1.1	12	71	2.7	0.04	0.2	0.2	A
29	6	33	21.0	37- 48.0	121- 56.8	6.1	2.2	20	47	3.1	0.08	0.3	0.3	A
29	6	59	29.7	37- 48.4	121- 56.6	5.1	1.2	13	69	2.4	0.06	0.2	0.3	A
29	7	9	55.0	37- 48.5	121- 56.1	5.3	1.1	13	69	2.2	0.04	0.2	0.2	A
29	7	46	37.7	37- 47.9	121- 56.8	6.0	1.1	13	74	3.3	0.07	0.3	0.3	A
29	7	53	20.8	37- 47.8	121- 56.6	6.3	1.2	13	76	3.4	0.04	0.1	0.2	A
29	8	6	30.1	37- 48.2	121- 57.0	5.0	1.6	15	53	2.9	0.08	0.3	0.4	A
29	9	15	11.8	37- 48.0	121- 56.7	6.1	2.3	15	53	3.2	0.05	0.2	0.2	A
29	9	21	58.7	37- 48.1	121- 56.7	6.0	2.1	17	53	2.9	0.06	0.2	0.2	A
29	9	29	18.5	37- 47.8	121- 57.0	6.1	1.8	15	51	3.6	0.06	0.2	0.3	A
29	9	42	5.0	37- 47.9	121- 56.8	6.4	1.3	13	75	3.3	0.05	0.2	0.2	A
29	9	57	22.1	37- 47.9	121- 56.9	6.4	1.2	12	75	3.4	0.05	0.2	0.2	A
29	11	20	41.3	37- 47.8	121- 56.9	6.4	1.4	13	76	3.5	0.05	0.2	0.2	A
29	11	29	47.3	37- 48.0	121- 57.1	6.1	1.4	14	53	3.3	0.12	0.5	0.5	A
29	11	49	7.7	37- 47.9	121- 56.9	6.1	1.6	14	53	3.3	0.05	0.2	0.2	A
29	12	6	49.6	37- 48.2	121- 56.6	5.8	2.2	20	50	2.8	0.09	0.3	0.3	A
29	13	49	2.8	37- 47.9	121- 57.0	6.3	1.6	15	52	3.4	0.04	0.2	0.2	A
29	14	1	37.9	37- 49.1	121- 56.1	7.0	1.6	13	53	1.1	0.07	0.3	0.2	A
29	22	56	26.9	37- 48.5	121- 56.2	5.5	1.4	12	69	2.2	0.03	0.1	0.2	A
29	23	11	52.6	37- 48.5	121- 56.2	5.6	1.6	12	68	2.1	0.05	0.2	0.3	A
30	0	40	44.9	37- 47.9	121- 56.9	6.3	1.6	13	58	3.4	0.05	0.2	0.2	A
30	4	31	2.6	37- 47.9	121- 57.1	6.7	0.9	10	75	3.5	0.04	0.2	0.3	A
30	6	9	16.2	37- 48.7	121- 55.5	5.5	1.0	12	65	2.1	0.04	0.1	0.2	A
30	6	27	53.4	37- 48.6	121- 55.6	5.1	1.0	12	66	2.1	0.05	0.2	0.3	A
30	6	45	4.6	37- 48.6	121- 55.6	5.4	1.0	12	66	2.2	0.05	0.2	0.3	A
30	8	55	58.6	37- 48.8	121- 55.6	5.2	1.7	14	58	2.0	0.03	0.1	0.2	A
30	8	58	42.8	37- 48.6	121- 55.7	5.8	1.0	12	66	2.1	0.03	0.1	0.2	A
30	9	57	9.7	37- 48.0	121- 56.9	6.2	1.3	12	74	3.2	0.02	0.1	0.1	A
30	20	22	12.7	37- 48.7	121- 55.7	5.4	1.1	12	66	2.1	0.03	0.1	0.2	A
31	2	57	45.3	37- 48.5	121- 56.7	5.1	2.1	16	49	2.3	0.06	0.2	0.3	A
31	5	3	35.1	37- 47.9	121- 56.9	6.4	1.5	14	57	3.3	0.05	0.2	0.2	A
31	5	5	50.6	37- 47.9	121- 57.0	6.5	1.3	14	57	3.3	0.04	0.2	0.2	A
31	11	2	40.3	37- 47.8	121- 57.4	6.2	1.4	12	59	3.7	0.04	0.2	0.3	A
31	13	57	28.3	37- 47.9	121- 57.2	5.9	1.6	14	57	3.5	0.05	0.2	0.2	A
JUN 1	0	12	16.1	37- 47.9	121- 57.4	6.6	1.3	11	83	3.6	0.03	0.1	0.2	A
1	4	49	37.2	37- 48.1	121- 56.8	5.0	2.3	15	55	3.0	0.05	0.2	0.2	A
1	5	49	30.8	37- 47.9	121- 56.8	7.0	1.3	12	75	3.3	0.07	0.3	0.2	A
1	10	42	16.6	37- 48.5	121- 55.8	7.8	1.2	8	98	6.5	0.11	0.8	0.8	B
1	20	1	17.2	37- 47.0	121- 58.0	5.3	1.2	11	81	5.1	0.07	0.3	0.7	A
2	0	46	42.0	37- 48.5	121- 56.0	5.0	1.0	11	71	2.2	0.10	0.4	0.6	A
2	12	3	50.7	37- 47.5	121- 56.3	5.6	1.5	12	85	4.0	0.04	0.2	0.2	A
3	4	14	45.2	37- 47.4	121- 56.4	5.7	2.4	25	48	4.1	0.15	0.4	0.5	A
3	12	59	24.6	37- 48.1	121- 56.6	5.8	1.5	13	72	2.9	0.04	0.1	0.2	A
3	20	13	22.8	37- 47.9	121- 57.0	6.3	1.5	13	53	3.5	0.05	0.2	0.2	A
4	3	2	37.4	37- 47.9	121- 56.4	5.7	1.4	13	75	3.2	0.04	0.1	0.2	A
4	10	18	38.5	37- 47.9	121- 57.0	6.3	1.3	12	75	3.5	0.06	0.3	0.3	A

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
JUN 4	13	22	12.5	37- 49.4	121- 57.1	5.0	1.4	12	59	1.2	0.07	0.3	0.4	A
4	15	55	39.5	37- 48.2	121- 56.2	5.6	1.4	13	71	2.6	0.05	0.2	0.3	A
4	16	12	50.4	37- 47.2	121- 58.0	5.3	1.5	13	79	5.0	0.06	0.2	0.3	A
5	8	33	41.5	37- 48.1	121- 57.1	6.6	1.8	11	95	3.1	0.13	0.6	0.7	B
5	8	49	60.0	37- 47.9	121- 56.8	6.0	2.1	15	50	3.3	0.05	0.2	0.2	A
5	9	54	9.9	37- 47.1	121- 58.1	4.9	1.3	12	73	5.0	0.06	0.2	0.3	A
6	4	25	55.4	37- 47.1	121- 58.5	5.3	1.6	10	89	8.5	0.08	0.4	0.6	B
6	22	49	20.9	37- 47.7	121- 57.0	5.9	1.0	8	90	8.3	0.03	0.2	0.3	B
7	10	41	28.3	37- 47.8	121- 56.4	5.5	1.6	8	119	7.9	0.09	0.6	0.8	B
7	18	36	40.7	37- 48.0	121- 57.3	6.4	1.8	6	112	7.9	0.03	0.1	0.1	B
8	3	55	13.2	37- 48.1	121- 55.8	10.0	1.3	7	103	7.4	0.21	0.5	0.5	B
10	5	20	30.1	37- 47.6	121- 57.2	5.7	1.0	6	99	8.5	0.01	0.1	0.1	B
10	8	57	37.8	37- 48.8	121- 55.8	9.8	1.0	7	95	5.9	0.20	0.7	0.8	B
10	12	17	52.2	37- 47.1	121- 58.1	5.0	0.9	6	98	8.9	0.04	0.4	1.2	B
10	13	12	1.6	37- 47.2	121- 58.3	5.8	1.4	8	90	8.7	0.03	0.2	0.2	B
10	16	21	19.6	37- 48.4	121- 57.1	5.7	1.4	6	161	7.2	0.03	0.3	0.4	B
10	17	23	3.0	37- 49.1	121- 55.4	8.7	1.0	6	94	5.5	0.07	1.4	2.0	B
10	21	9	30.0	37- 48.7	121- 56.7	5.0	1.1	6	104	7.9	0.06	0.5	0.9	B
11	22	13	6.2	37- 47.3	121- 56.4	5.7	1.1	7	106	10.2	0.03	0.2	0.3	B
11	22	14	50.6	37- 47.4	121- 56.4	5.5	1.3	8	86	10.0	0.02	0.1	0.1	B
11	23	23	47.9	37- 47.3	121- 56.4	5.8	1.6	7	107	10.3	0.01	0.0	0.1	B
11	23	32	55.2	37- 47.6	121- 56.7	5.0	3.4	21	84	9.8	0.08	0.3	0.4	B
11	23	37	15.9	37- 47.7	121- 56.3	5.7	1.6	7	103	9.5	0.03	0.2	0.3	B
11	23	39	48.9	37- 47.5	121- 56.8	5.0	3.1	20	84	10.0	0.06	0.2	0.3	B
11	23	44	53.8	37- 47.1	121- 56.4	5.0	2.4	17	83	10.6	0.10	0.4	0.6	B
11	23	45	48.9	37- 47.3	121- 56.4	6.2	2.2	8	106	10.3	0.06	0.4	0.5	B
11	23	46	52.9	37- 48.1	121- 56.5	5.8	2.0	7	99	9.0	0.05	0.3	0.5	B
11	23	47	35.4	37- 47.6	121- 56.4	6.1	0.8	6	104	9.7	0.06	0.4	0.6	B
11	23	48	34.7	37- 47.3	121- 56.5	5.0	2.7	21	81	10.4	0.08	0.3	0.4	B
11	23	52	12.6	37- 46.9	121- 56.7	5.0	1.0	6	109	11.0	0.07	0.2	1.4	B
11	23	52	27.2	37- 47.6	121- 56.3	5.8	1.7	7	104	9.6	0.04	0.3	0.4	B
12	0	0	43.4	37- 48.0	121- 56.5	5.9	1.6	7	99	9.0	0.04	0.3	0.4	B
12	0	6	12.6	37- 47.6	121- 56.4	5.9	1.8	9	88	9.8	0.04	0.2	0.2	B
12	0	6	17.5	37- 47.6	121- 56.3	5.8	2.0	8	105	9.7	0.05	0.3	0.4	B
12	0	9	58.0	37- 47.7	121- 56.5	5.8	1.3	6	159	10.8	0.03	0.2	0.2	B
12	0	12	9.6	37- 47.3	121- 56.6	6.4	1.2	6	106	10.4	0.06	0.7	1.2	B
12	0	12	46.3	37- 47.7	121- 56.4	6.3	1.0	6	103	9.6	0.03	0.3	0.5	B
12	0	21	21.1	37- 48.4	121- 56.3	6.6	1.8	10	94	8.3	0.14	0.8	0.9	B
12	0	30	5.2	37- 48.2	121- 56.8	6.1	1.0	7	97	8.8	0.10	0.8	1.1	B
12	0	39	24.2	37- 48.3	121- 57.1	5.0	3.1	22	91	8.8	0.09	0.3	0.4	B
12	0	50	34.5	37- 48.0	121- 56.7	5.0	1.0	7	99	9.2	0.09	0.5	0.9	B
12	0	53	37.4	37- 48.0	121- 56.5	5.7	1.1	7	99	9.0	0.01	0.0	0.1	B
12	0	58	7.9	37- 47.6	121- 56.4	5.6	1.9	9	88	9.8	0.03	0.1	0.2	B
12	1	11	27.1	37- 48.5	121- 56.0	5.6	1.0	6	98	8.1	0.02	0.1	0.3	B
12	2	5	24.2	37- 47.4	121- 56.6	6.2	1.6	8	86	10.2	0.05	0.3	0.4	B
12	2	10	57.9	37- 48.6	121- 56.2	5.0	2.2	11	172	11.0	0.06	0.3	0.4	B
12	2	28	26.8	37- 48.2	121- 56.8	5.0	1.6	7	98	8.7	0.09	0.6	1.0	B
12	3	30	3.3	37- 47.2	121- 56.5	5.0	4.3	25	80	10.6	0.07	0.3	0.4	B
12	3	30	18.1	37- 47.0	121- 56.6	5.0	4.3	6	108	10.9	0.06	0.5	0.9	B
12	3	30	49.9	37- 47.9	121- 56.9	7.6	4.1	6	98	9.3	0.05	0.5	0.7	B
12	3	33	47.8	37- 47.1	121- 56.5	5.0	2.7	18	80	10.7	0.08	0.3	0.5	B
12	3	34	55.3	37- 47.4	121- 56.4	5.8	1.7	7	106	10.1	0.03	0.2	0.2	B
12	3	35	36.5	37- 49.1	121- 57.2	5.0	1.0	6	177	9.6	0.18	1.1	1.4	C
12	3	38	4.2	37- 47.1	121- 56.0	6.0	1.9	9	80	10.6	0.05	0.3	0.3	B
12	3	57	48.8	37- 47.2	121- 56.3	5.6	2.5	21	79	10.5	0.07	0.2	0.3	B
12	3	58	56.6	37- 47.4	121- 56.4	5.9	1.2	7	105	10.1	0.04	0.3	0.4	B
12	3	59	59.6	37- 47.5	121- 56.6	5.0	1.3	6	155	10.8	0.03	0.3	0.8	B
12	4	0	15.7	37- 48.3	121- 56.4	7.2	1.2	6	97	8.4	0.08	0.6	1.5	B
12	4	5	1.5	37- 48.4	121- 56.3	5.0	1.6	6	96	8.2	0.03	0.2	0.5	B
12	4	5	58.8	37- 48.1	121- 56.8	5.0	3.0	7	97	8.9	0.08	0.7	0.9	B

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
JUN 12	4	7	1.4	37- 48.5	121- 56.2	5.6	1.7	7	96	8.0	0.03	0.2	0.3	B
12	4	19	2.4	37- 48.0	121- 56.5	6.1	1.1	7	100	9.1	0.07	0.5	0.6	B
12	5	12	12.1	37- 47.8	121- 56.5	5.6	1.6	7	102	9.5	0.01	0.1	0.1	B
12	5	19	43.1	37- 47.9	121- 56.6	5.0	1.7	8	100	9.3	0.03	0.2	0.3	B
12	5	53	39.6	37- 47.5	121- 56.4	6.4	1.8	8	87	9.9	0.06	0.4	0.6	B
12	6	7	44.9	37- 47.9	121- 56.7	6.4	1.5	8	94	9.3	0.01	0.1	0.1	B
12	6	26	46.5	37- 48.2	121- 56.8	5.5	1.6	6	98	8.8	0.01	0.1	0.1	B
12	6	34	0.7	37- 46.9	121- 56.4	5.5	3.2	24	78	11.0	0.06	0.2	0.3	B
12	7	11	25.2	37- 48.2	121- 56.5	5.0	1.3	7	98	8.8	0.03	0.2	0.3	B
12	7	39	24.3	37- 48.0	121- 56.6	5.0	2.3	9	94	9.2	0.12	0.7	1.0	B
12	7	55	51.9	37- 48.0	121- 56.4	5.7	1.4	7	100	9.0	0.03	0.2	0.3	B
12	8	5	15.0	37- 48.4	121- 56.4	5.8	1.8	7	96	8.3	0.01	0.1	0.1	B
12	8	38	48.8	37- 47.7	121- 56.3	5.0	2.1	13	89	9.6	0.09	0.4	0.6	B
12	9	5	32.6	37- 48.0	121- 56.5	6.3	1.1	7	100	9.1	0.05	0.4	0.5	B
12	9	56	47.1	37- 48.3	121- 56.4	5.0	1.3	7	97	8.5	0.04	0.3	0.5	B
12	10	7	6.8	37- 48.1	121- 56.3	5.7	1.3	7	100	8.8	0.04	0.2	0.3	B
12	10	38	54.8	37- 47.8	121- 56.4	6.3	0.9	6	161	11.0	0.04	0.4	0.5	B
12	10	41	56.3	37- 47.8	121- 56.2	6.1	1.2	7	103	9.3	0.08	0.5	0.7	B
12	11	21	10.9	37- 47.9	121- 56.4	6.4	1.5	8	91	9.3	0.03	0.2	0.2	B
12	12	31	24.4	37- 46.4	121- 56.2	6.7	1.3	7	137	12.0	0.05	0.5	0.6	B
12	14	11	8.8	37- 47.8	121- 56.3	6.4	1.5	7	90	9.3	0.02	0.2	0.2	B
12	14	55	20.3	37- 47.4	121- 56.5	5.0	2.2	13	87	10.1	0.10	0.5	0.6	B
12	15	53	42.9	37- 48.4	121- 56.3	5.7	1.2	6	98	8.3	0.03	0.2	0.2	B
12	15	55	8.6	37- 47.8	121- 56.6	6.1	1.1	7	101	9.5	0.06	0.4	0.5	B
12	15	55	40.2	37- 48.0	121- 57.0	3.9	1.6	6	98	9.3	0.01	0.1	0.3	B
12	16	3	31.2	37- 48.1	121- 56.7	5.0	2.8	20	87	9.0	0.08	0.3	0.4	B
12	16	3	36.3	37- 48.0	121- 56.9	5.0	4.0	7	98	9.2	0.06	0.4	0.6	B
12	16	8	33.4	37- 47.5	121- 56.5	5.0	2.4	11	87	10.0	0.10	0.5	0.7	B
12	16	10	50.6	37- 47.3	121- 56.6	5.0	3.2	25	82	10.3	0.10	0.3	0.5	B
12	16	11	52.3	37- 47.3	121- 55.9	7.5	1.3	6	109	10.1	0.16	0.2	0.3	B
12	16	25	24.1	37- 47.9	121- 56.7	5.6	1.5	7	100	9.3	0.04	0.3	0.4	B
12	16	26	5.1	37- 47.6	121- 56.5	6.1	2.2	8	89	9.7	0.04	0.2	0.3	B
12	16	31	25.7	37- 47.3	121- 56.4	5.9	1.6	6	106	10.3	0.09	0.6	0.9	B
12	16	44	0.4	37- 47.2	121- 56.5	6.4	1.0	7	107	10.5	0.04	0.2	0.4	B
12	16	49	16.8	37- 47.8	121- 56.4	6.3	1.0	6	102	9.5	0.03	0.3	0.5	B
12	16	57	57.4	37- 47.8	121- 56.7	5.0	2.3	15	92	9.5	0.09	0.4	0.5	B
12	17	5	7.4	37- 47.3	121- 56.2	6.3	1.1	6	108	10.3	0.04	0.3	0.5	B
12	17	5	57.5	37- 47.4	121- 56.3	6.2	1.7	9	85	10.2	0.04	0.2	0.2	B
12	17	9	46.6	37- 47.7	121- 56.4	6.3	1.1	7	103	9.5	0.05	0.4	0.6	B
12	17	10	49.8	37- 47.8	121- 57.8	5.0	2.5	19	93	9.0	0.08	0.3	0.8	B
12	17	12	25.4	37- 47.8	121- 56.3	6.8	1.7	8	89	9.4	0.08	0.5	0.5	B
12	17	19	16.1	37- 48.1	121- 56.8	5.5	1.2	7	98	9.0	0.04	0.2	0.4	B
12	17	41	54.9	37- 47.9	121- 56.5	6.1	2.5	8	92	9.3	0.02	0.1	0.1	B
12	17	43	25.1	37- 47.4	121- 56.6	5.6	1.7	9	87	10.1	0.10	0.5	0.7	B
12	17	44	28.0	37- 48.3	121- 56.7	6.2	0.9	6	99	8.6	0.14	1.5	2.4	B
12	17	44	49.5	37- 47.7	121- 56.4	6.1	1.2	6	103	9.5	0.01	0.1	0.1	B
12	17	57	48.5	37- 49.4	121- 55.2	15.0	1.3	6	96	6.2	0.27	0.5	1.0	B
12	18	0	48.8	37- 47.3	121- 56.5	5.0	2.6	16	81	10.4	0.06	0.2	0.3	B
12	18	5	37.6	37- 47.9	121- 56.8	5.0	2.4	15	94	9.4	0.08	0.3	0.5	B
12	18	8	57.6	37- 47.7	121- 56.4	6.1	1.3	7	103	9.5	0.03	0.2	0.2	B
12	18	44	46.1	37- 48.4	121- 57.0	6.0	1.2	7	108	2.5	0.06	0.7	0.6	B
12	19	0	37.6	37- 47.0	121- 57.1	3.1	2.0	12	82	5.1	0.11	0.6	0.9	B
12	19	2	19.2	37- 47.5	121- 56.4	6.2	1.6	9	104	3.9	0.04	0.2	0.2	B
12	19	9	42.0	37- 48.1	121- 56.4	5.6	1.3	9	99	2.9	0.05	0.3	0.3	B
12	19	39	26.2	37- 47.7	121- 56.3	6.2	1.2	8	104	3.7	0.02	0.2	0.2	B
12	19	53	40.5	37- 48.1	121- 56.4	6.2	1.6	11	84	2.9	0.12	0.6	0.6	A
12	20	12	1.6	37- 47.7	121- 56.4	5.6	1.2	10	80	1.4	0.04	0.2	0.2	A
12	20	23	7.6	37- 47.8	121- 57.0	5.3	1.7	11	95	1.9	0.04	0.2	0.2	B
12	20	28	21.1	37- 48.5	121- 57.7	7.1	1.2	8	126	2.9	0.05	0.4	0.4	B
12	20	45	25.3	37- 48.8	121- 57.5	7.6	1.7	12	130	2.3	0.09	0.5	0.3	B

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
JUN 12	20	58	14.8	37- 47.6	121- 56.4	6.2	2.4	12	79	1.2	0.04	0.2	0.1	A
12	21	3	30.5	37- 48.0	121- 56.4	6.4	1.4	10	93	1.9	0.08	0.4	0.4	B
12	21	10	49.1	37- 47.9	121- 56.8	5.0	1.1	8	91	1.9	0.07	0.4	0.4	B
12	21	32	20.1	37- 47.5	121- 56.4	6.1	1.4	10	86	0.9	0.02	0.1	0.1	A
12	21	54	11.9	37- 47.4	121- 56.4	5.9	1.1	11	76	0.8	0.03	0.1	0.1	A
12	22	34	52.3	37- 48.3	121- 56.7	5.8	2.3	15	93	2.5	0.07	0.2	0.2	B
12	22	38	34.0	37- 48.1	121- 56.6	5.9	1.0	11	90	2.2	0.03	0.2	0.2	B
12	22	54	19.6	37- 47.7	121- 56.4	5.9	2.1	15	80	1.4	0.04	0.1	0.1	A
12	22	54	38.6	37- 47.9	121- 56.4	5.6	2.9	21	74	1.7	0.10	0.3	0.3	A
13	0	19	48.3	37- 47.9	121- 56.8	5.0	1.5	13	51	1.9	0.07	0.3	0.3	A
13	1	49	2.9	37- 47.7	121- 56.4	6.4	1.1	13	49	1.4	0.03	0.2	0.2	A
13	2	38	9.9	37- 47.9	121- 56.4	5.8	1.1	11	92	1.7	0.04	0.2	0.2	B
13	3	3	38.6	37- 47.6	121- 56.4	6.2	1.5	14	48	1.1	0.04	0.2	0.2	A
13	3	41	8.9	37- 47.8	121- 56.4	5.0	1.7	12	66	1.5	0.10	0.4	0.5	A
13	3	57	28.6	37- 47.9	121- 56.9	6.8	1.4	13	51	1.8	0.03	0.1	0.1	A
13	4	18	12.4	37- 47.7	121- 56.8	6.3	1.1	12	49	1.4	0.06	0.3	0.3	A
13	5	13	58.2	37- 47.7	121- 56.3	6.0	1.8	14	52	1.4	0.03	0.1	0.1	A
13	6	50	1.8	37- 47.4	121- 56.4	5.6	2.2	17	48	0.8	0.09	0.3	0.3	A
13	7	42	40.9	37- 47.9	121- 57.0	7.0	1.1	11	58	1.9	0.02	0.1	0.1	A
13	7	48	32.3	37- 47.8	121- 55.2	5.0	1.2	11	90	2.3	0.12	0.5	0.6	A
13	8	1	39.1	37- 47.5	121- 56.4	5.6	2.4	23	48	1.0	0.10	0.3	0.3	A
13	9	11	23.2	37- 48.4	121- 56.7	5.0	1.1	14	54	2.5	0.06	0.2	0.2	A
13	12	36	56.9	37- 47.6	121- 56.4	6.1	1.2	12	67	1.3	0.04	0.1	0.2	A
13	12	45	29.6	37- 47.6	121- 56.4	6.2	1.9	17	48	1.2	0.08	0.3	0.2	A
13	16	2	11.3	37- 46.8	121- 56.3	6.1	1.0	11	90	0.4	0.04	0.2	0.2	B
13	16	21	1.2	37- 48.2	121- 56.4	5.2	1.2	11	91	2.3	0.04	0.2	0.2	B
13	21	28	5.6	37- 47.7	121- 57.1	6.5	1.2	12	91	1.7	0.05	0.2	0.2	B
13	22	59	57.6	37- 48.7	121- 57.1	6.3	1.1	13	51	2.0	0.05	0.2	0.2	A
13	23	12	59.5	37- 47.9	121- 56.4	5.9	1.0	12	66	1.6	0.03	0.1	0.2	A
14	0	42	0.5	37- 47.9	121- 56.4	5.9	1.2	12	65	1.8	0.05	0.2	0.2	A
14	0	49	17.4	37- 47.9	121- 56.4	6.0	1.6	12	65	1.8	0.03	0.1	0.1	A
14	1	8	35.3	37- 48.7	121- 55.6	6.6	1.3	12	64	2.0	0.07	0.3	0.3	A
14	1	38	23.0	37- 46.9	121- 56.9	6.7	2.1	17	46	0.8	0.07	0.3	0.3	A
14	2	45	41.7	37- 48.1	121- 56.7	5.9	1.2	12	55	2.1	0.04	0.2	0.2	A
14	9	11	9.0	37- 47.6	121- 56.4	5.4	3.0	26	48	1.1	0.06	0.2	0.2	A
14	9	13	54.1	37- 47.6	121- 56.4	5.6	1.1	12	92	1.1	0.04	0.2	0.2	B
14	9	18	2.0	37- 47.8	121- 56.4	5.9	1.0	9	74	1.5	0.03	0.1	0.2	A
14	9	18	9.5	37- 47.8	121- 56.4	5.0	3.0	32	49	1.6	0.08	0.2	0.2	A
14	9	18	50.6	37- 47.4	121- 56.4	6.8	1.4	6	100	0.8	0.04	0.4	0.6	B
14	9	38	42.3	37- 47.4	121- 56.4	6.1	1.2	12	66	0.7	0.09	0.4	0.4	A
14	21	8	0.4	37- 48.4	121- 56.3	5.0	2.4	21	51	2.4	0.07	0.2	0.2	A
14	23	23	34.3	37- 48.6	121- 56.1	5.0	1.1	11	66	2.0	0.09	0.4	0.5	A
14	23	24	20.1	37- 47.9	121- 56.4	5.0	2.4	22	49	1.6	0.10	0.3	0.3	A
15	1	55	47.6	37- 48.2	121- 56.4	5.9	2.0	14	64	2.2	0.08	0.2	0.3	A
15	13	19	10.4	37- 47.6	121- 56.4	6.3	1.3	14	61	1.2	0.06	0.3	0.3	A
15	13	57	13.4	37- 48.9	121- 55.4	6.0	1.1	12	61	1.9	0.04	0.1	0.2	A
15	14	0	35.9	37- 47.8	121- 56.5	6.1	1.1	12	61	1.6	0.02	0.1	0.1	A
15	14	56	14.1	37- 48.7	121- 55.7	4.5	1.0	12	96	2.0	0.07	0.3	0.3	B
16	6	29	8.5	37- 47.8	121- 56.4	5.9	1.2	11	66	1.6	0.04	0.2	0.2	A
16	8	3	14.1	37- 47.6	121- 56.4	5.5	1.4	12	67	1.1	0.09	0.4	0.4	A
17	2	54	28.1	37- 47.8	121- 56.4	5.9	1.9	12	75	3.4	0.03	0.1	0.2	A
17	5	28	5.1	37- 48.7	121- 57.2	6.2	1.1	13	52	2.2	0.05	0.2	0.2	A
17	10	42	35.1	37- 47.5	121- 58.0	7.0	1.2	12	60	2.6	0.07	0.3	0.3	A
17	10	56	53.9	37- 48.1	121- 56.6	5.6	1.3	11	73	3.0	0.03	0.2	0.2	A
17	12	15	12.6	37- 47.5	121- 58.2	7.5	1.5	15	58	2.9	0.07	0.3	0.3	A
17	19	6	41.6	37- 48.0	121- 56.4	6.1	1.1	12	76	1.9	0.05	0.3	0.2	A
17	19	39	6.3	37- 47.9	121- 57.2	7.2	1.3	13	58	3.5	0.04	0.2	0.2	A
18	12	31	29.2	37- 47.7	121- 56.4	6.2	1.4	14	50	1.3	0.04	0.2	0.1	A
18	22	18	54.5	37- 47.7	121- 56.3	5.9	1.7	12	77	3.6	0.03	0.1	0.1	A
19	4	1	45.4	37- 46.1	121- 56.4	6.5	1.0	12	99	1.6	0.05	0.2	0.3	B

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
JUN 19	7	38	41.5	37- 48.9	121- 55.6	6.0	1.1	12	63	1.8	0.04	0.2	0.2	A
19	10	32	42.2	37- 47.7	121- 56.2	6.4	1.1	11	77	1.4	0.03	0.2	0.2	A
19	11	20	10.6	37- 47.6	121- 56.4	6.0	1.1	11	78	3.8	0.05	0.2	0.4	A
19	16	14	32.8	37- 48.2	121- 56.4	5.1	1.4	12	63	2.3	0.04	0.1	0.2	A
20	3	47	11.8	37- 47.8	121- 56.4	5.6	1.1	11	76	3.5	0.08	0.3	0.5	A
20	16	40	15.3	37- 49.4	121- 57.1	6.0	1.4	12	61	1.1	0.07	0.3	0.3	A
20	18	22	32.1	37- 47.7	121- 56.4	6.3	1.2	12	67	1.4	0.05	0.2	0.2	A
20	18	42	13.4	37- 48.1	121- 56.5	6.1	1.3	12	62	2.0	0.03	0.1	0.1	A
21	0	12	55.4	37- 47.7	121- 56.4	5.9	1.3	12	67	1.3	0.09	0.3	0.3	A
22	14	17	2.0	37- 47.7	121- 56.4	5.0	1.5	12	74	1.3	0.07	0.3	0.3	A
22	14	36	28.1	37- 47.7	121- 56.4	5.0	1.7	11	74	1.3	0.07	0.3	0.3	A
22	14	37	5.8	37- 47.7	121- 56.4	5.0	2.1	11	74	1.4	0.04	0.2	0.2	A
24	12	22	33.9	37- 47.6	121- 57.9	6.8	2.1	20	61	2.5	0.07	0.3	0.2	A
25	1	36	34.4	37- 48.9	121- 57.2	6.0	1.0	10	104	1.9	0.05	0.3	0.2	B
25	2	0	36.7	37- 47.6	121- 56.4	5.8	1.7	13	98	1.1	0.05	0.2	0.2	B
26	14	54	4.2	37- 47.7	121- 56.4	5.9	1.1	10	80	1.3	0.06	0.2	0.3	A
26	20	52	32.0	37- 47.9	121- 56.4	5.7	1.5	12	82	1.7	0.03	0.1	0.1	A
27	17	54	12.8	37- 47.7	121- 56.8	5.9	1.3	11	81	1.6	0.03	0.1	0.1	A
28	0	19	31.9	37- 49.1	121- 58.0	4.4	1.2	11	123	1.8	0.08	0.3	0.3	B
28	17	25	48.6	37- 48.2	121- 56.7	6.4	1.1	10	94	1.9	0.04	0.2	0.2	B
28	21	19	20.3	37- 48.5	121- 56.7	5.3	2.5	15	87	2.0	0.07	0.3	0.3	A
29	6	27	45.9	37- 47.5	121- 56.4	5.8	1.4	12	73	2.6	0.03	0.1	0.1	A
29	13	19	49.2	37- 47.4	121- 56.8	5.0	1.5	13	69	2.3	0.09	0.4	0.5	A
29	13	20	22.4	37- 47.3	121- 56.5	5.5	1.1	12	71	2.4	0.03	0.2	0.1	A
29	13	20	26.1	37- 47.2	121- 56.5	5.3	1.5	10	138	2.1	0.08	0.5	0.4	B
29	13	22	1.8	37- 47.4	121- 56.6	5.5	1.0	12	70	2.4	0.05	0.2	0.2	A
30	4	47	14.6	37- 47.4	121- 56.6	5.6	1.8	14	67	2.4	0.04	0.2	0.1	A
JUL 1	2	7	30.8	37- 47.3	121- 56.4	6.0	1.2	12	72	2.4	0.04	0.2	0.1	A
1	15	31	12.1	37- 47.9	121- 56.4	5.3	2.4	22	75	2.4	0.09	0.3	0.2	A
2	21	54	51.8	37- 47.7	121- 56.6	5.5	1.2	12	75	1.3	0.03	0.1	0.1	A
2	23	14	25.8	37- 46.7	121- 57.1	5.3	1.9	15	55	1.1	0.05	0.2	0.1	A
4	17	20	26.6	37- 47.7	121- 56.4	5.8	2.0	18	75	1.3	0.04	0.1	0.1	A
5	5	27	53.1	37- 47.8	121- 56.6	5.0	2.7	19	77	2.2	0.13	0.4	0.4	A
5	5	28	46.3	37- 47.9	121- 56.6	5.4	2.9	27	77	2.2	0.11	0.3	0.2	A
5	5	29	57.7	37- 47.5	121- 57.1	5.7	1.4	6	132	1.8	0.03	0.6	0.7	B
6	2	33	26.5	37- 47.6	121- 56.5	5.6	2.3	22	71	2.5	0.06	0.2	0.1	A
6	3	43	41.2	37- 47.4	121- 56.4	5.9	1.2	12	72	2.6	0.02	0.1	0.1	A
6	20	41	23.3	37- 49.5	121- 57.4	7.6	1.2	11	112	1.6	0.06	0.3	0.3	B
7	12	18	24.0	37- 47.5	121- 56.4	6.0	1.3	15	72	0.9	0.05	0.2	0.1	A
8	7	5	1.1	37- 47.9	121- 56.3	5.9	1.2	13	79	1.8	0.04	0.2	0.2	A
9	8	58	28.3	37- 48.2	121- 57.2	4.3	1.4	14	99	1.2	0.06	0.2	0.2	B
9	19	29	55.3	37- 46.5	121- 57.2	5.0	1.3	14	50	0.8	0.07	0.3	0.3	A
10	5	38	42.4	37- 47.3	121- 58.0	5.7	0.9	11	99	1.5	0.05	0.3	0.2	B
14	15	29	49.6	37- 48.0	121- 56.4	6.5	1.6	13	83	1.8	0.07	0.3	0.2	A
14	18	8	10.3	37- 48.1	121- 57.1	4.6	1.9	15	96	1.4	0.06	0.2	0.2	B
17	23	58	3.5	37- 47.2	121- 58.1	5.7	1.5	16	73	1.7	0.05	0.2	0.2	A
18	5	43	3.5	37- 47.3	121- 58.2	6.2	1.0	11	88	1.5	0.06	0.3	0.3	A
19	5	9	35.1	37- 48.4	121- 56.2	4.9	1.3	12	82	2.4	0.04	0.2	0.1	A
20	3	38	46.4	37- 47.4	121- 56.4	5.4	1.0	13	72	0.8	0.03	0.1	0.1	A
20	11	1	19.1	37- 49.2	121- 55.4	6.0	1.2	11	99	1.6	0.03	0.1	0.2	B
22	18	18	11.9	37- 48.1	121- 56.4	5.6	1.3	11	84	2.1	0.07	0.3	0.4	A
24	18	50	28.8	37- 48.5	121- 56.7	4.4	2.8	27	86	2.1	0.07	0.2	0.1	A
24	18	59	12.5	37- 48.3	121- 57.0	4.7	1.4	14	97	1.7	0.04	0.2	0.1	B
24	18	59	28.1	37- 48.2	121- 57.0	4.2	1.6	14	97	1.5	0.07	0.2	0.2	B
24	19	13	16.1	37- 48.4	121- 56.6	4.5	1.9	15	93	2.2	0.06	0.2	0.2	B
24	19	14	8.8	37- 48.4	121- 56.6	4.7	1.2	11	93	2.2	0.04	0.2	0.1	B
24	19	26	15.1	37- 48.2	121- 56.8	4.7	2.0	15	94	1.8	0.07	0.3	0.2	B
24	19	40	25.6	37- 48.3	121- 56.4	5.0	1.1	11	101	2.4	0.04	0.2	0.1	B
24	20	1	59.2	37- 48.4	121- 56.6	4.9	1.1	11	91	2.4	0.03	0.1	0.1	B
24	23	13	41.3	37- 48.1	121- 56.9	5.1	1.3	12	94	1.7	0.06	0.3	0.2	B

TABLE 2—*continued*

1970	HR	MN	SEC	LAT N	LONG W	DEPTH	MAG	NO	GAP	DMIN	RMS	ERH	ERZ	Q
JUL 25	2	33	15.3	37- 48.5	121- 56.4	4.8	1.5	15	86	2.2	0.05	0.2	0.1	A
25	8	28	27.6	37- 47.8	121- 56.3	6.4	1.2	12	77	1.6	0.04	0.2	0.2	A
25	16	35	6.0	37- 47.3	121- 58.1	5.5	2.1	20	74	1.6	0.06	0.2	0.2	A
25	17	7	23.9	37- 47.3	121- 58.0	6.4	1.4	13	65	1.5	0.04	0.2	0.2	A
29	15	19	26.4	37- 48.4	121- 57.2	5.0	1.4	9	102	1.3	0.06	0.3	0.4	B
31	2	54	15.5	37- 48.4	121- 55.9	5.0	1.6	7	99	8.2	0.07	0.5	0.8	B

* For each event, the following data are given:
Origin time in Greenwich Civil Time: date, hour (HR), minute (MN), and second (SEC).
Epicenter in degrees and minutes of north latitude (LAT N) and west longitude (LONG W).
DEPTH, depth of focus in kilometers.
MAG, magnitude of the earthquake.
NO, number of stations used in locating earthquake.
GAP, largest azimuthal separation in degrees between stations.
DMIN, epicentral distance in kilometers to the nearest station.
RMS, root-mean-square error of the time residuals

$$\left[= \sqrt{\sum_i R_i^2/NO} \right]$$

where R_i is the observed seismic-wave arrival time less the computed time at the ith station.
ERH, standard error of the epicenter in kilometers.

$$\left[= \sqrt{SDX^2 + SDY^2} \right]$$

where SDX and SDY are the standard errors in latitude and longitude, respectively, of the epicenter.
ERZ, standard error of the depth in kilometers.
Q, solution quality of the hypocenter. This measure is intended to indicate the general reliability of each solution:

Q	Epicenter	Focal Depth
A	excellent	good
B	good	fair
C	fair	poor
D	poor	poor

Q is based on both the nature of the station distribution with respect to the earthquake and the statistical measure of the solution. These two factors are each rated independently according to the following scheme:

Station Distribution

	NO	GAP	DMIN
A	≧6	≦90°	≦DEPTH or 5 km
B	≧6	≦135°	≦2 × DEPTH or 10 km
C	≧6	≦180°	≦50 km
D	Others		

Statistical Measures

	RMS (sec)	ERH (km)	ERZ (km)
A	<0.15	<1.0	<2.0
B	<0.30	<2.5	<5.0
C	<0.50	<5.0	
D	Others		

Q is taken as the average of the ratings from the two schemes, i.e., an A and a C yield a B, and two B's yield a B. When the two ratings are only one level apart the lower one is used, i.e., an A and a B yield a B.

Bolt (1960). Tests with and without azimuthal weighting showed little difference in hypocenter solutions. This suggests that the distance weighting introduced before was effective in correcting bias arising from uneven distribution of stations.

The accuracy of the hypocenters determined for the Danville earthquakes may be summarized as follows: epicenters were determined to ±0.5 km on the average; focal depth was ±1 km whenever close-in stations were available, otherwise, ±2 km or more. This level of accuracy is similar to that achieved by Eaton, O'Neill, and Murdock (1970) for the aftershocks of the Parkfield-Cholame earthquake of 1966. It is a considerable improvement over the results from most regional near-earthquake networks where epicenters are determined to ±5 km.

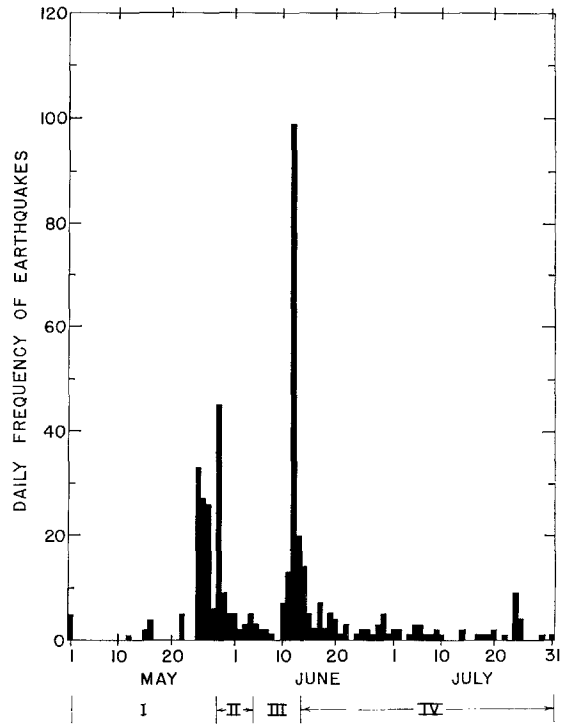

FIG. 4. Daily frequency of earthquakes near Danville from May 1 to July 31, 1970. Temporary stations were in full operation during periods marked II and IV.

EARTHQUAKE DISTRIBUTION

Figure 4 is a daily frequency plot of the Danville earthquakes. Seismic activity was high from May 26 to 29 and again from June 11 to 13. Temporary stations were deployed immediately after the first felt earthquake on May 26. A week later, the extensive seismic activity appeared to be over and the temporary stations were removed. Subsequently, another series of earthquakes occurred, and we reoccupied the temporary stations. These stations were in operation until the end of July, when the seismic activity was at a low level. Thereafter, seismic activity was monitored by three telemetered stations installed in the vicinity of the earthquake area.

The use of temporary stations did not affect the uniformity of the data presented in Figure 4, because the events were selected from results of routine processing of our network data. This is confirmed by the frequency plot shown in Figure 5. The

linear fit of the data to magnitude 1.2 indicates that the data are complete for earthquakes with magnitude greater than 1.2. The b slope is 0.7 and is typical of the San Francisco Bay area earthquakes. Bufe (1970) studied the variation of b slope as a function of time and found that periods of maximum elastic-strain release were preceded and accompanied by marked decrease in b (i.e., by a relative increase in larger shocks).

Epicenters of the 426 Danville earthquakes studied are shown in Figure 6 with symbol size proportional to the earthquake magnitude. The entire epicentral area of the Danville earthquakes is within a radius of 3 km; the main active area is about 1 km in radius. The larger earthquakes lie in a zone that trends north-northwest, roughly parallel to the Calaveras fault zone. With the exception of about 20 small events, epicenters of the majority of the earthquakes occurred at least 2 km east of the Calaveras fault zone.

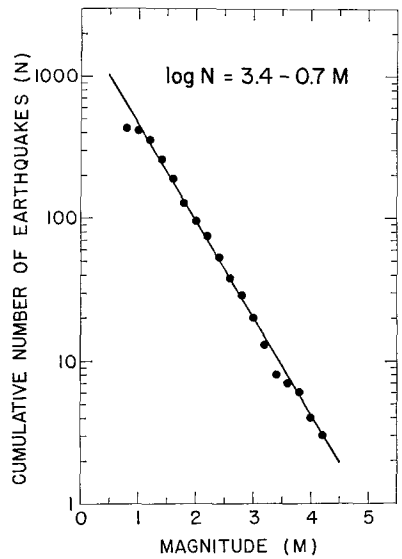

FIG. 5. Cumulative number of earthquakes versus magnitude.

Whether or not the Danville earthquakes are related to the Calaveras fault is difficult to resolve. In the vicinity of Danville, the Calaveras fault is concealed beneath alluvium of the San Ramon Valley, so that its surface extent as shown in Figure 6 is inferred and its dip is unknown. A cross-section of Danville earthquake foci (A—B line in Figure 6) is shown in Figure 7. Although depths of about one-half of the earthquake foci are not well determined (the alignment of foci along 5-km focal depth is due to a provision in the location program that uncertain focal depths be fixed arbitrarily at 5 km), the distribution of foci is similar to that obtained when only well-determined foci were plotted.

Distribution of foci in Figure 7 does not suggest an obvious relationship between Danville earthquakes and the Calaveras fault. A dip of about 70° eastward for the Calaveras fault would be required if one were to place the Danville earthquakes on the Calaveras fault. From Figure 6, one might suggest that the Danville earthquakes occurred along an extension of the Pleasanton fault. However, there is a 3-km gap of seismic activity between the epicentral region and the mapped surface trace of the Pleasanton fault. The epicentral area was examined by Brabb and Lee on June 22,

1970, to determine if there were any surface features that could be attributed to the earthquakes. The terrain is rolling, grass-covered pasture land. No ground cracks or any other geological phenomena commonly associated with earthquakes were found.

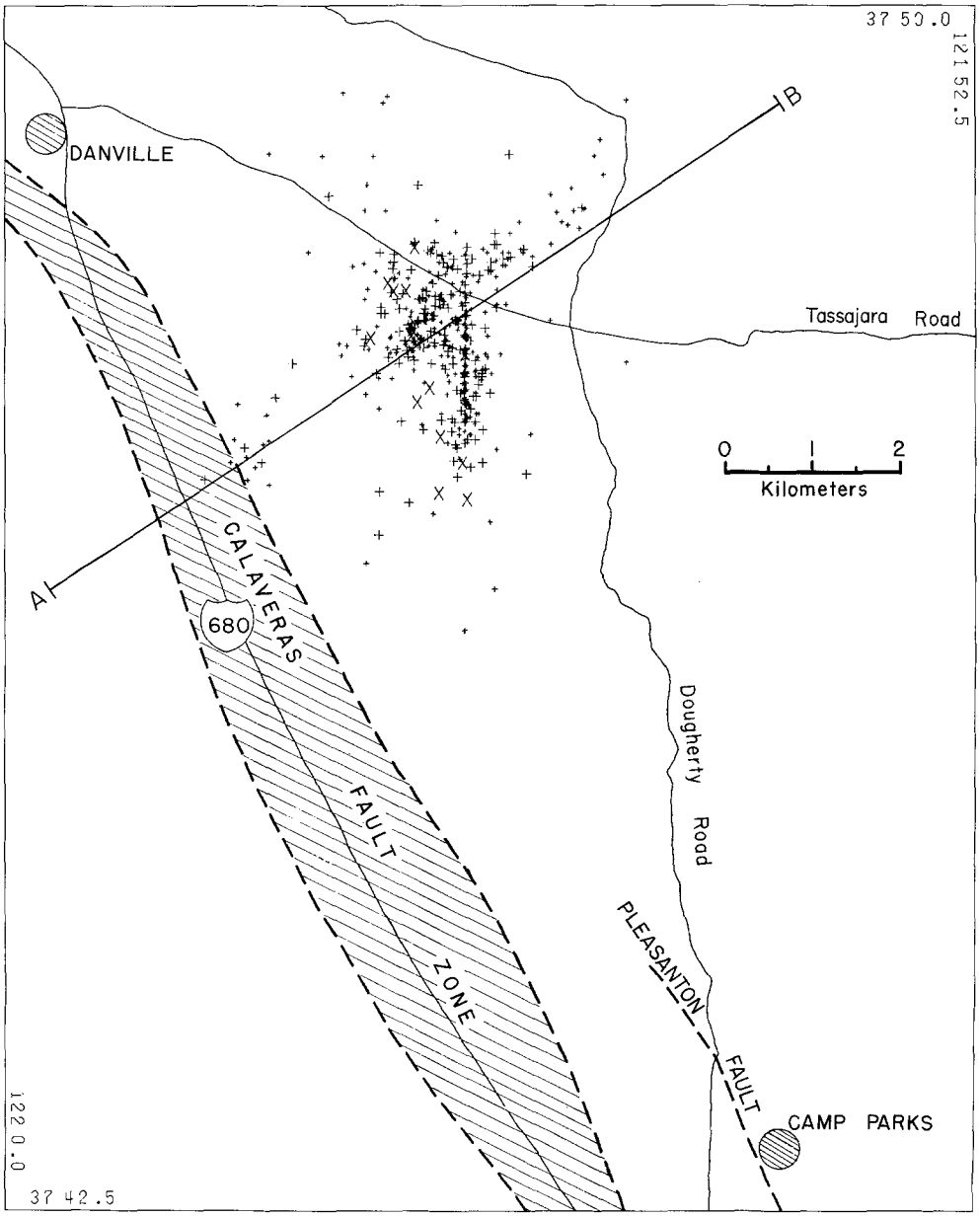

FIG. 6. Map showing epicenters of Danville earthquakes. This map corresponds to the *shaded square* in Figure 1. Small + denotes magnitude less than 1.5; large +, magnitude between 1.5 to 3; and ×, magnitude greater than or equal to 3.

The temporal distribution of Danville earthquakes is illustrated by Figure 8. Epicenters are shown for four periods: (1) May 1 to 24, before the swarm-type activity; (2) May 25 to June 9, first extensive seismic activity; (3) June 10 to 23, second extensive seismic activity; and (4) June 24 to July 31, post swarm-type activity. The

focal region of the Danville earthquakes appears to enlarge in successive periods. Wood and Allen (1971) observed anomalous microtilt on June 9, preceding the largest Danville earthquake on June 12. Repeated geodimeter measurements by Savage and Kinoshita (1971) on three lines located near Danville suggest possible changes of about 1 cm in the Diablo-Sunol line, which is consistent with right-lateral slip, but the data are not sufficiently precise to prove such changes.

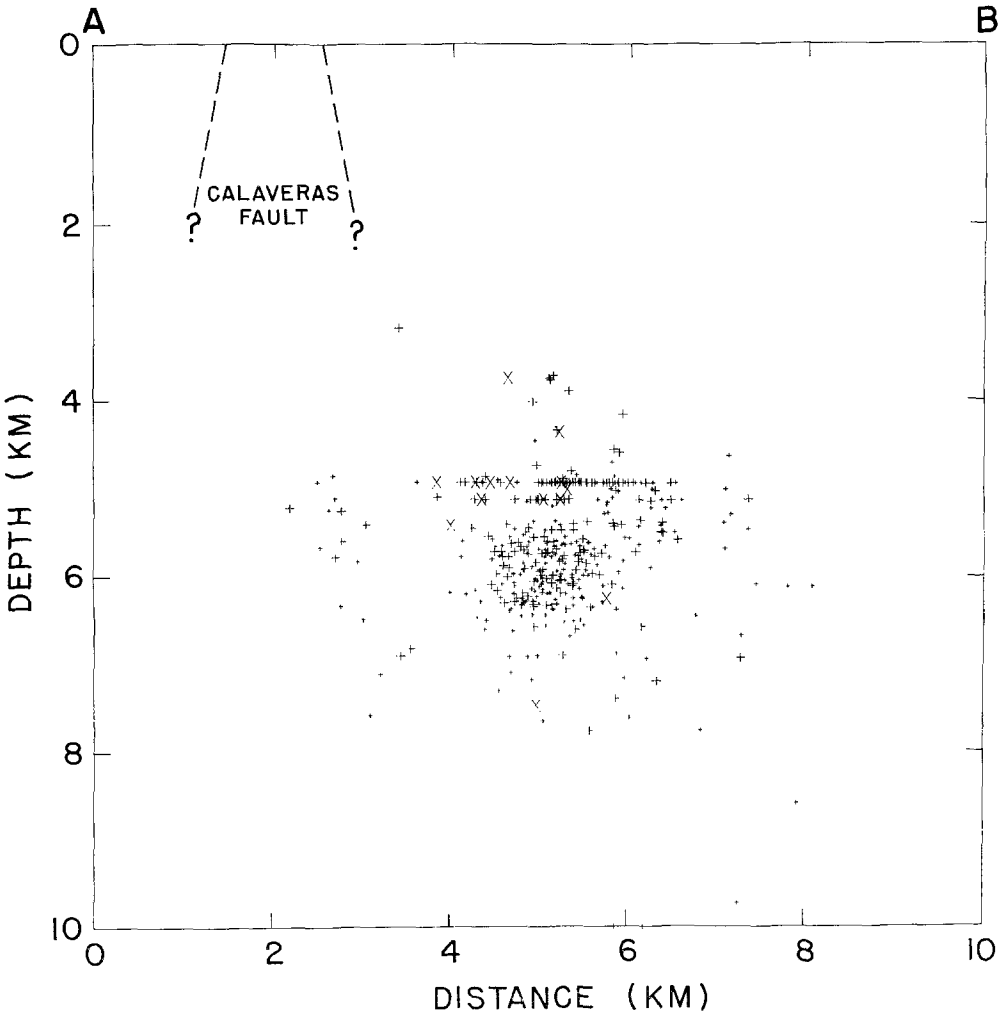

FIG. 7. Cross-section of earthquake foci (line A—B on Figure 6). Symbol size is proportional to magnitude as explained in Figure 6.

FOCAL MECHANISM

The dense concentration of seismographs also permits detailed study of the first-motion pattern of the Danville earthquakes. Figure 9 shows a typical first-motion pattern for the event at 15:31 on July 1 (magnitude = 2.4). The two nodal planes are well defined ($\pm 5°$), suggesting that faulting during this earthquake was either right-lateral strike-slip with a strike of N 35°W or left-lateral with a strike of N 55°E. For this solution, both of the fault planes are nearly vertical, dipping 80° to 90°.

Of the 426 earthquakes studied, about 100 yield good fault-plane solutions. Illustrat-

ing the fault-plane solutions over the epicentral area, however, requires a selection of solutions to be plotted because most of these events occurred too close to one another. Consequently, 23 well-recorded earthquakes were selected to cover the epicentral

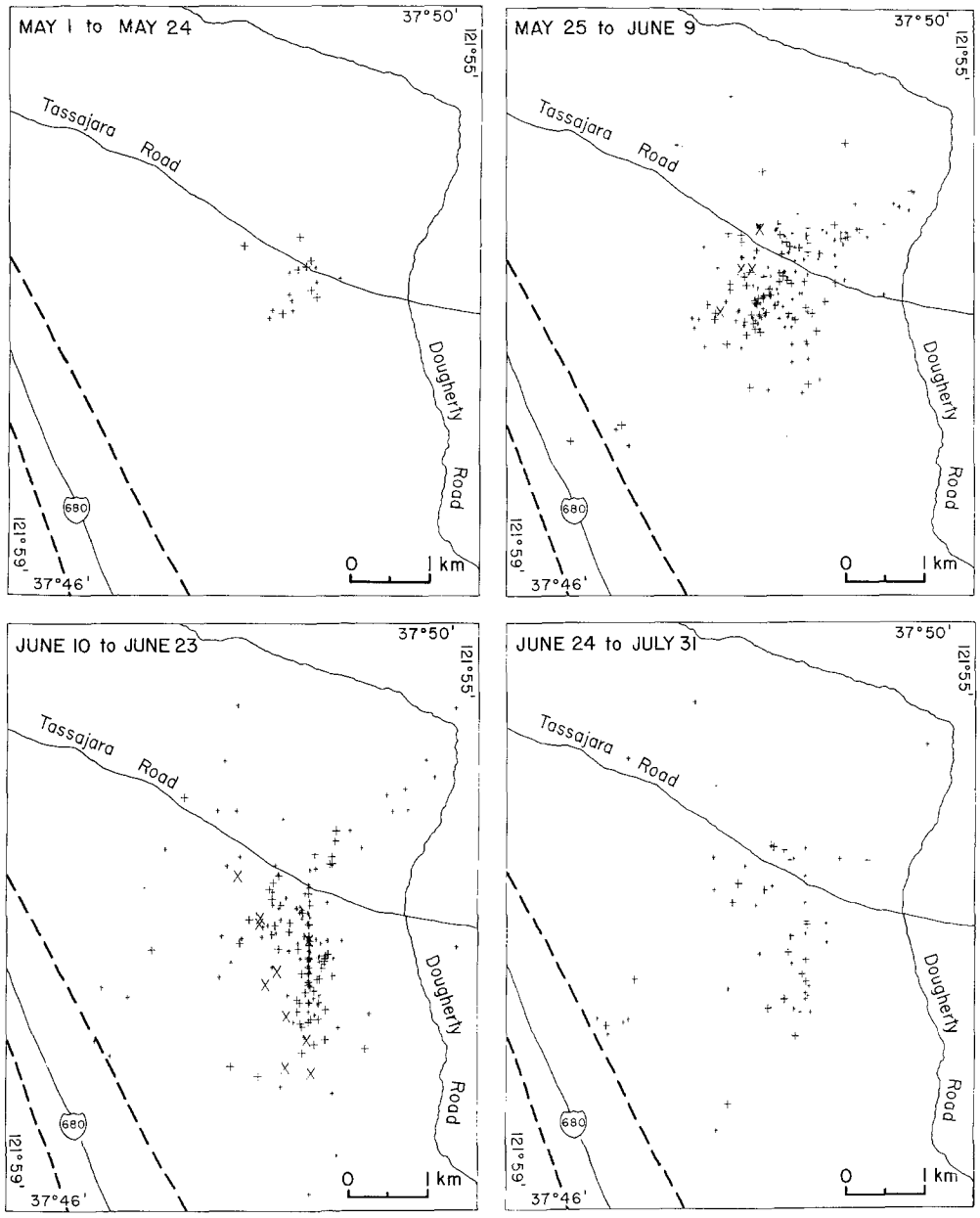

FIG. 8. Map showing epicenters of Danville earthquakes for 4 time periods. Symbol size is proportional to magnitude as explained in Figure 6.

area and their fault-plane solutions are shown in Figure 10. Individually, they are similar to the one shown in Figure 9. Because major faults in the San Francisco Bay region are right-lateral strike-slip and strike nearly northwest, it is reasonable to choose the northwest-striking nodal plane as the fault plane for the Danville earthquakes.

Discussion

The roughly spherical pattern of earthquake foci southeast of Danville suggests that the earthquake activity could be related to some type of piercement structure presently about 6 km below the surface of the ground. This piercement structure could be a relatively cold plug of mafic or ultramafic rock lubricated by serpentine, as postulated by Pampeyan (1963, p. 18–20) for Mt. Diablo nearby. The Danville earthquakes could have been caused by the release of strain, accumulated from right-lateral movements of the San Andreas fault system (Bolt, Lomnitz, and McEvilly, 1968; Eaton, Lee, and Pakiser, 1970) in the piercement structure. An alternative explanation is that the Danville earthquakes occurred along a previously unrecognized fault. This fault could be a splay from the Calaveras fault zone, or an extension of the Pleasanton or Livermore faults, or it may not be related to any of these faults.

Additional data would be helpful in determining the origin of the Danville earthquakes. Piercement structures could probably be detected by gravity and seismic surveys, and volcanic rocks, by magnetic and geothermal surveys. Aerial photographs taken under different light and vegetation conditions may provide information about the structure of the rocks, but conventional geological mapping will not help unless more of the rocks are uncovered.

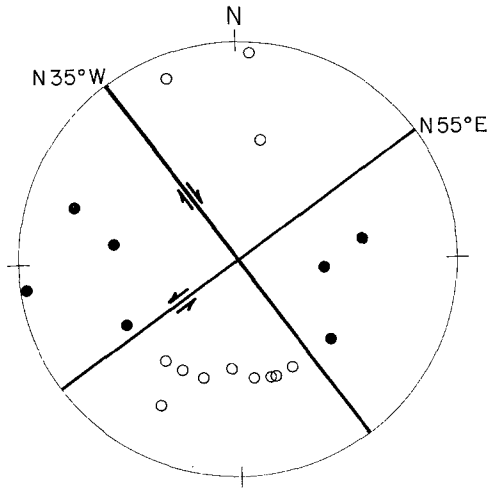

Fig. 9. First-motion pattern of a typical well-recorded Danville earthquake (15:31, July 1, 1970; magnitude = 2.4). The ● indicates compression; the ○, dilatation. The plot is an equal area projection of the lower focal hemisphere.

Although the origin of the Danville earthquakes is uncertain, the fact remains that a potentially hazardous area has been discovered, and the importance of a dense seismograph network for accurate location of small earthquakes has been demonstrated. Seismic data show that the Danville area is active, that the activity has been mainly within a 1-km spherical region at a depth of 6 km, and that most, if not all, of the activity is related to right-lateral faulting.

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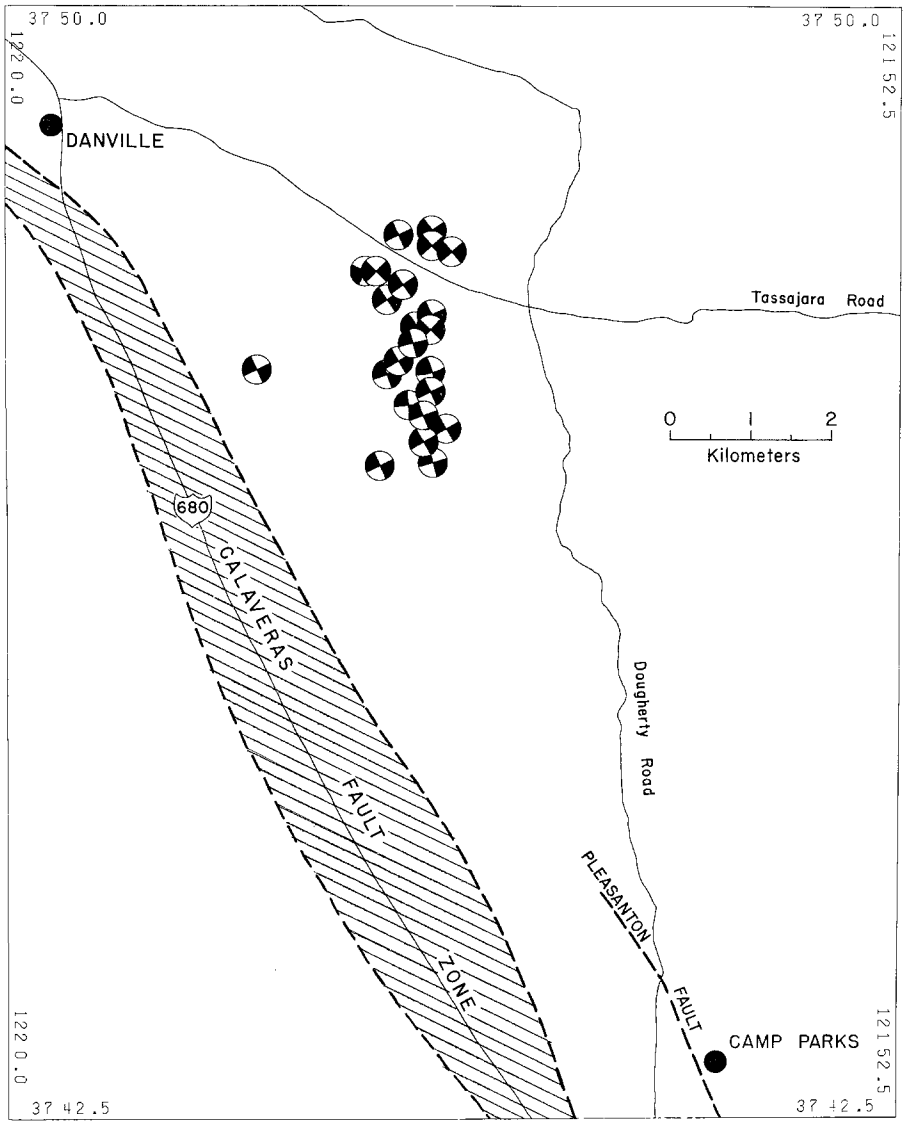

FIG. 10. Map showing the fault-plane solutions of selected well-recorded Danville earthquakes. *Black quadrant* denotes compression; *white quadrant*, dilatation.

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